THE JOURNAL

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DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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INDEX.

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLI, No. 1. 76TH YEAR. JANUARY, 1901

Electrical Section—Mechanical and Engineering Section.

Proceedings of the Joint Meeting, held Thursday, November 15, 1900.

MR. JOHN F. ROWLAND, JR., in the Chair.

SUBJECT FOR DISCUSSION:

THE ELECTRIC DISTRIBUTION OF POWER IN WORKSHOPS.

The discussion was opened by PROFESSOR F. B. CROCKER, of Columbia University, New York City, who spoke as follows:

The use of electric motors in factories, mills and other manufacturing establishments has now become so important that it well deserves the careful attention of electrical and mechanical engineers. This new combination of the electrical and mechanical branches of engineering is not much more than five years old, and yet its introduction and success have been so general that it promises to be adopted almost universally in the next five or ten years.

The electric driving of tools and machines must possess important advantages in order to achieve such rapid and general success in its very short career. The principal points of advantage that it possesses may be summed up under the following heads:

(1) *Saving in Power.*—This is generally the first point to be considered, but is by no means the most important, as cost of power in most factories and mills is only 1 to 3 per cent. of the total expenses, the cost of labor being usually many times greater. It is, however, a fact that electric driving usually secures a considerable saving in the consumption of power.

(2) *Cost of Buildings.*—Since heavy overhead shafting is not required for electric driving, the buildings may be made much lighter and cheaper in construction than for ordinary mechanical driving.

(3) *Cost of Equipment.*—The relative expense of equipping a factory with electric motors or with belting and shafting depends upon circumstances, but would usually be greater for the former. The difference, however, is not very great, and the saving in buildings noted above would generally make up the balance. The depreciation on the electrical plant can easily be made less than that on belting and shafting; lubrication is also less and the attention required is no greater.

(4) *Arrangement of Machinery.*—The use of electric motors enables the machinery to be placed in almost any desired position. It is not necessary that they should be parallel or arranged in rows or placed at any particular angle with respect to each other. With belting and shafting, on the other hand, the machinery must be arranged in a very particular manner and very often it has to be placed where the light is poor, and accessibility or other important matters have to be sacrificed.

(5) *Clear Head Room.*—The elimination of overhead belting and shafting by the use of motors gives a clear head room, which enables overhead cranes to be used freely, and also avoids the great obstruction to light and air, which is a serious objection to the old-fashioned methods.

(6) *Cleanliness.*—The dripping of oil from overhead shafting is a constant source of trouble and the dirt thrown out from belting is an even worse enemy to cleanliness. The

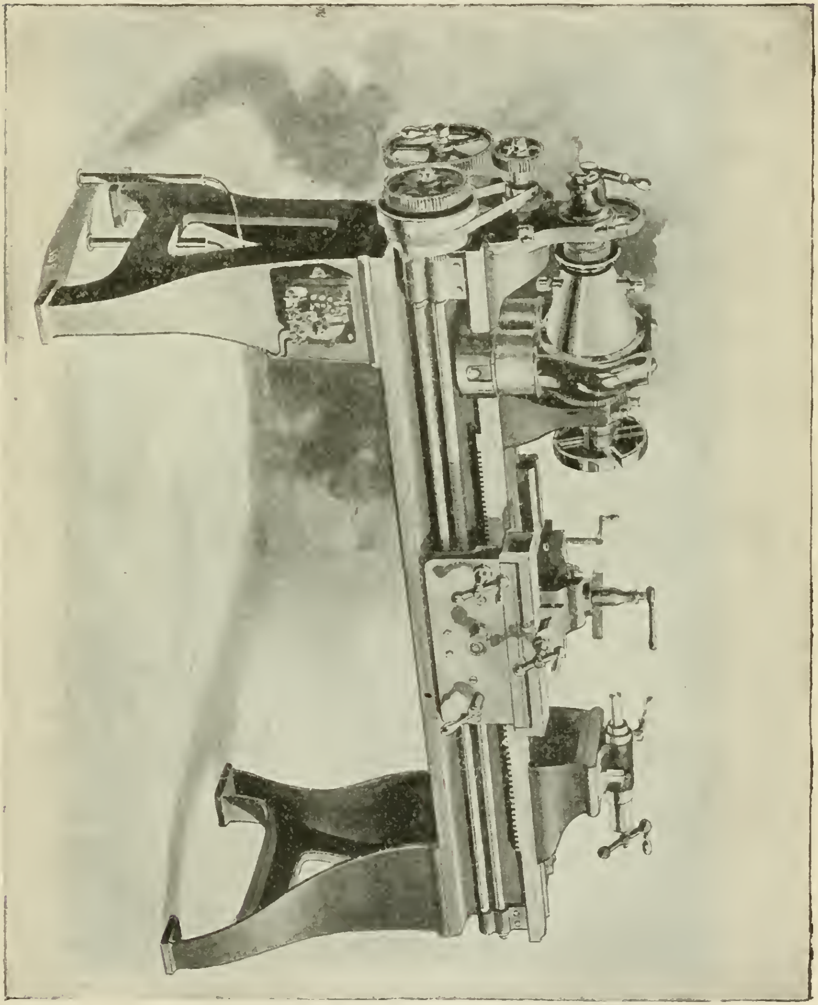

FIG. 1.—Lathe directly driven by electric motor.

agitation of dust by belting and shafting keeps it in constant circulation, so that it penetrates everywhere and everything.

(7) *Health of Employés.*—On account of advantages in regard to light and air and the reduction in dust and dirt, it is found by actual experience that the health of those who work with electrical driving machinery is improved. In the

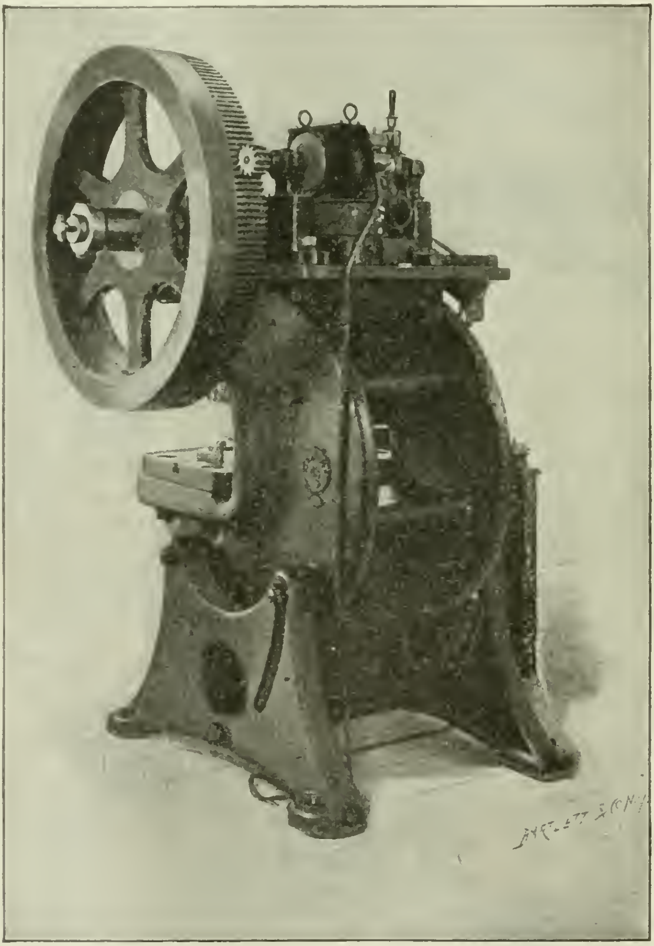

FIG. 2.—Electric motor geared to punching press.

Government Printing Office in Washington, one of the largest in the world, it was found that the sick list was decreased 20 to 40 per cent. after electric motors were introduced.

(8) *Convenience for Detached Buildings.*—The electrical method enables detached buildings to be reached easily and economically, which is not possible with ordinary methods. The buildings, like the machinery within them, can be

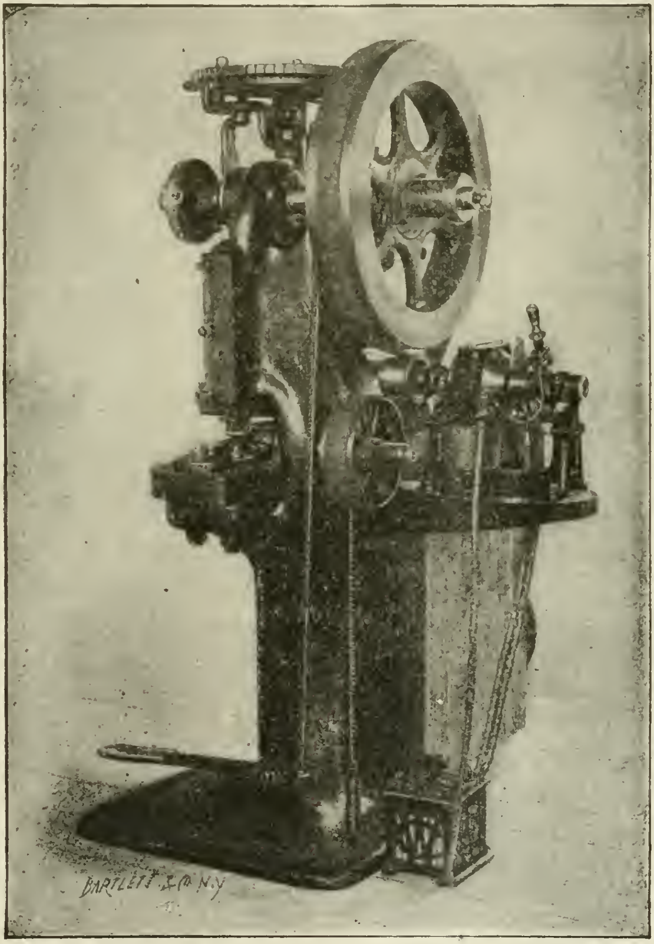

FIG. 3.—Electric motor belted with idler to notching press.

located for general convenience, and not with special regard to supplying them with power.

(9) *Freedom for Growth.*—For similar reasons it is a simple matter to extend a building, or add another in any direction

or at any time as desired, whereas with the old method of driving, the shafting must be installed originally with the idea of extension, or else it must be replaced later. In fact, the length to which shafting can be run is very limited, and the extending of a building, or the erection of another, may require the installation of an additional steam-power plant, which is decidedly objectionable. The electrical plan enables all the power generation to be effected at one point and wherever it is most convenient, even though some distance away.

(10) *Shut-downs Less Frequent and Less Serious.*—An accident in an electrically driven plant usually has a local effect only, simply shutting down one or a few machines, while with belting and shafting the breaking or slipping off of a belt may require the whole or a large portion of the machinery to be stopped, in order to make the repair. In a large establishment a delay of even ten minutes represents a very considerable item in wages, and the interruption of the work is demoralizing. It might be argued that the central plant might break down, but that is just as true of a mechanical installation as of an electrical one.

(11) *Speed Control.*—The variation of speed that is possible with electric driving, and the convenience as well as range of control, are very great advantages with most kinds of machinery. The operator can drive the tool to its limit of capacity, and can on the other hand instantly relieve it of strain, if he finds it necessary. With mechanical driving the means of speed control are far more limited and less convenient than with electric motors. The shifting of the belt on a cone pulley, for example, and the throwing in and out of different sets of gearing is a clumsy operation which a workman is not likely to attempt in order to gain slightly in the efficiency or rapidity of working.

(12) *Increase of Output.*—Owing to the many advantages named above, but especially on account of clear head room for overhead crane service, and convenience of speed control, it is found that the output of manufacturing establishments is materially increased in most cases by the use of electric driving. It is often found that this gain actually

amounts to 20 or 30 per cent. or even more, with the same floor space, machinery and number of workmen. This is the most important advantage of all, because it secures an increase in income without any increase in investment, labor or expense, except perhaps for material. In many cases the output is raised and at the same time the labor item is reduced.

I will now show a number of lantern slides illustrating the various methods of applying and connecting motors to the different kinds of machinery. It will be noticed that no general plan can be followed, since it depends upon the size, shape and character of the apparatus. The many different arrangements may be classed, however, under three general headings: First, *direct connection* of motor and machine, as, for example, when a fan is mounted directly upon the shaft of a motor, or when a motor and pump are directly connected. Second, *connection by means of gearing*, which is often employed when a large reduction in speed is required. Third, *connection by means of belting*, where moderate reduction in speed is sufficient. The flexibility of the belt is sometimes an advantage, since it does not produce the shock upon the motor and wide variations in current which occur with direct connection or gearing. In a punching press, for example, the belting relieves the motor of a large portion of the sudden strain and rush of current to which it would otherwise be subjected.

MR. SAMUEL M. VAUCLAIN, superintendent of the Baldwin Locomotive Works, gave an instructive account of the experiences which he had made in connection with the introduction of electric driving in the shops of that establishment, from the introduction of the great electrically-operated travelling cranes to the finally successful adaptation of independent electric motors to machine tools. Many difficulties were encountered, but in the end all were satisfactorily overcome, and the speaker was now prepared to place on record his cordial endorsement of the modern method, on the score of its many and great advantages over the old style power transmission by lines of shafting, which it is displacing.

The speaker favored belt connections for tools in which there was considerable jar, on account of the elasticity of the method. He pointed out also that machine tools as at present built were not adapted for motors, and in so adapting them he would not alter the structure of the tool so that motor and tool would be one unit, but would provide room so that any motor from the market could be applied as an extra device.

He dwelt at some length upon the important economies in the saving of floor space and in operating expenses which had been realized in the Baldwin works by the introduction of the electric driving system, in testimony of which he made the statement that "if we should abandon electric driving, our manufactured product would now cost us from 20 per cent. to 25 per cent. more for labor;" and again, "were it not for electric driving, the Baldwin Locomotive Works would have to cover 40 per cent. more floor space than they now do, to maintain their present output."

Mr. Vauclain said, in conclusion, that while the question of the saving in power which the adoption of electric motors permitted was of importance, it was by no means the deciding factor, and that he would put in electric driving systems not only if they saved no power, but even if they required several times the power of a shaft and belting system to operate them.

Mr. Gano S. Dunn:—It gives me pleasure to participate in this discussion, because I believe one of the greatest engineering advances that have been made in recent years is in course of accomplishing in the introduction of electrical power into our factories, and that by such introduction so greatly will be altered the cost of many kinds of product that we shall experience a readjustment along economic lines that will have important bearings farther than we can see. Already I believe electric power distribution is one of the factors which are enabling American industries to undersell and to give better deliveries than the industries of other countries, and the reasons for this tremendous advantage it indeed behooves us to investigate and to discuss within the widest limits.

I have been particularly impressed with the remarks of Mr. Vauclain, and his statements as to the saving in pay-roll and floor space enjoyed from the use of electric power. Had such testimony been with those of us who in the early days first worked to bring such installations about, our task would have been much easier. Electric power originally based its claim for attention upon the amount of energy saved in the distribution of power from the engine-room of a factory to the work at the tools, and of course included in this advantage the reduction in first cost of power plant in view of the necessity for fewer boilers, smaller engines, etc. There were many factories which introduced electric power because we engaged to save from 20 to 60 per cent. of their coal bills; but such savings as these are not what has caused the tremendous activity in electric power equipment that is to-day spreading all over this country and setting such a standard that the builder who equips his factory at this moment with other than electric power is considered to be behind the times.

A consideration of the question shows that in the largest machine shops and factories the cost of power forms but a small proportion of the cost of the finished product, averaging in fact between 1 and 2 per cent. The argument therefore for electric power based on saving $\frac{1}{5}$ or even $\frac{3}{5}$ of this small item, which would have represented a saving of but a fraction of a per cent. in the cost of the finished product, was not very strong. But those who first introduced electric power on this basis found that they were making other savings than those that had been promised, which might be called indirect savings.

Professor Crocker has so ably enumerated these savings that I shall not repeat them, but I am particularly glad to see them so thoroughly confirmed in what Mr. Vauclain has related to us of the experience of the Baldwin Locomotive Works.

If it is argued the saving of a fraction of a per cent. in the cost of goods from economy in the power item is not of much importance, surely this cannot be said where the savings amount to 20 or 25 per cent. of the whole labor item.

Savings of this kind are enormous. They would pay in many cases for the whole electric equipment in a short period, and it is to these that the present electrical activity in factories is owing.

Without speaking further on the general aspects of the question, I would dwell upon the methods of obtaining adjustability and controllability of speeds, one of the great advantages accompanying electrical power, and will discuss some of the devices that have so far been used for this purpose.

In order not to occupy too much time, I shall refer only to the most important means. Among these are control by armature resistance. This is used in railway practice and for crane service, and other similar duty, characterized by intermittent operation and variable torque. It is effective, but inefficient, since it really operates by varying the voltage at the terminals of the motor, securing this variation by throttling, and thereby wasting, the energy of the operating current; but it is so simple and hardy that it is used very generally wherever the object of control is variable speed as distinguished from fixed speed capable of adjustment, these two types of control being embodied in cranes and lathes respectively.

Control by resistance lacks the feature of stability of speed, or that characteristic of shunt wound electric motors operating at constant potential, by virtue of which they maintain practically constant speed without respect to their load. The methods of control by resistance are so generally known that an allusion to them is here sufficient.

Next comes the system of control by field resistance, which operates by affecting the field strength of shunt wound motors, giving increased speed in proportion to the amount the field is weakened. The reason the speed increases instead of decreasing when the field strength is weakened, is that an essential condition of operation is that the counter electro-motive force of the motor must at all times be nearly equal to the direct electro-motive force of the line. Weakening of the field tends to reduce the counter electromotive force and compels the motor to increase its speed, to

restore by this means the counter electro-motive force of which it was robbed by the lowering of the field strength.

This system is of maximum efficiency, there being no losses except those in the motor itself, and the field regulator loss, which is insignificant.

It has the very desirable feature of a practically continuous variation over the whole of its range of speed change, the latter being subdivisible into steps indefinitely fine; but it has the following disadvantages:

With the increase of the motor's speed, there is, if the torque demanded remains constant, an exactly proportional increase in the horse-power it is called upon to develop, and yet to meet this increased duty it finds itself possessed of a weaker instead of a stronger field. Should the demand for torque increase, as an accompaniment to the demand for increase of speed, the above condition is aggravated.

The result of these facts is that unless the motor is made very much larger than is required for the actual horse-power demanded by its work, it is subject to internal losses from perturbation of field, to poor regulation and possibility of bucking, and to sparking which would prove destructive.

On the assumption of constant torque and capacity limited by commutation, the limits of successful speed control through the agency of the motor's field are at the extremes of a range of about 33 per cent. increase above a minimum speed. This requires a motor of which the capacity calculated at minimum speed would be about $33\frac{1}{3}$ per cent. greater than the horse-power demanded at maximum speed, or about 76 per cent. greater than the horse-power demanded at minimum speed. A given motor, of which the normal speed is the minimum desired, must not be called upon at maximum speed for an output greater than its normal capacity multiplied by the ratio of the minimum speed to the maximum. An example will, perhaps, make the matter clearer.

Given a lathe, in which it is required to increase the cutting speed $33\frac{1}{3}$ per cent. without changing the depth of cut or feed. If, at the low cutting speed, the lathe required a motor developing 5·6 horse-power at 850 revolutions per

minute, at the high cutting speed the motor would run at 1,125 revolutions per minute and would develop 7·5 horse-power, and would have to be of a rating of 10 horse-power at 850 revolutions per minute.

Applying our rule in this case, the ratio of minimum to maximum speed is 1 : $1\frac{1}{3}$, which is equal to 75 per cent., and 75 per cent. of 10 horse-power is $7\frac{1}{2}$ horse-power. That there is a considerable increase of first cost attending this system is easily seen.

Control by variation of voltage of the circuit is similar in efficiency and in speed characteristics to control by field regulation just described, and for the same conditions of torque and capacity limits, has the enormous advantage of requiring no increase in capacity of the motors.

For obtaining variation of voltage there are a number of methods, among them the connection of two armatures in parallel or in series, or its equivalent, the use of a single armature with two windings and two commutators which may be so connected. With the armatures in series, each receives but half the voltage it receives when in parallel.

The most perfect method of controlling by variation of voltage is the Leonard method, which is embodied in several forms. In the simple Leonard system a motor drives a dynamo which in turn drives the working motor. The variation of the field strength of the dynamo causes its voltage to vary correspondingly, and the speed of the working motor to follow closely these variations. A reversal of voltage reverses also the working motor. If voltage is permitted to remain at a particular value, the speed of the motor will be fixed at a corresponding speed. This method gives beautiful control, so perfect in fact that it is what is used on the battleships of the United States Navy for operating the great turrets and aiming the guns in their horizontal movements. It is possessed of a property by which not only is the motor prevented from falling below the particular speed for which the voltage has been set, but is also prevented from remaining above that speed through the influence of momentum or other causes.

The facility of handling, together with this braking

effect, has led to the adoption of the Leonard systems for operating roll tables in steel mills, and other work of similar character. I have seen an enormous table taken at full speed across a mill and stopped suddenly within a quarter of an inch of a previously made chalk mark, all so smoothly and with such freedom from shock as to seem wonderful.

But the Leonard system has its drawback in its high first cost, although this is considerably offset by a low cost of maintenance. The simple system described requires, besides the working motor, two additional machines of approximately the same capacity as the working motor, and although Mr. Leonard has developed what is known as the "retard and boost" system, which gives similar results with extra machinery of but half the capacity required in his simple system, the first cost is still comparatively high; all of which has resulted in the relegation of the Leonard system to special duties on large and important tools where flexibility of control is of paramount importance.

The most practical system of controlling speeds through the agency of voltage is the establishment throughout a shop of multiple voltage circuits, which maintain permanently six or more fixed voltages of different value, to any one of which the motor may be connected at will.

A system of six fixed voltages may be distributed by four wires, and gives a sufficient number of speeds for most purposes. Where finer subdivisions are required, they may be obtained by a combination of the armature or field resistance methods with the multiple voltage circuits, speeds between those given by the fixed voltages being secured by introducing various amounts of resistance into the armature circuit or by variations in field strength.

For constant torque service, the multiple voltage system requires no increase in the capacity of the working motor, and lends itself particularly well to machine shop practice, in that not all the tools in a shop require adjustable speed.

In fact, if the lighting of a factory is also taken into consideration, probably but one-half of the total load will be of a character best distributed at a fixed voltage, in which

case this part may be served by the outside wires of the 4-wire system, and the intermediate wires, which will be considerably smaller in size, need to be led only to the tools where adjustable speed is in demand.

Without discussing several other little used methods of electrical control of speed, I have now referred to those directly involved in factory distribution. But supplementing these must be used the various mechanical methods of speed changing already well known. Where changes of torque accompany changes of speed, mechanical devices are necessary, unless one is willing to use a motor larger than the size demanded by the power required, to accommodate, when called upon, the increased torques that accompany reductions in speed. A nest of gears or a pair of cone pulleys have the property of increasing torque in proportion to decreasing speed, and in this respect exactly meet the conditions.

They have the disadvantages, however, of requiring stoppage of work for changing speed, which causes a workman, by reason of this inconvenience, often to neglect to change his speed in cases where by so doing he could increase the output of his machine.

As a great deal of the work in factory distribution is of the kind in which torque changes accompany speed changes, the best solution is to use a combination of the mechanical devices, with a reasonable increase in the capacity of the motor. This will give all the advantages of electrical control over a reasonable range of speed, which range may be made applicable to whatever speeds and torques are desired beyond its limits, by adjustments of the mechanical connection ratio.

Mr. Vauclain mentioned that machine tools he would buy with the intention of driving by electric motors, he would not have altered by their builders, but would apply the power from the motors in the same manner as the tools had been designed to have the power supplied by belts. I believe he means this to refer, however, only to the smaller and simpler tools where there are no complicated belting systems. For this class of work I most fully agree with him,

since the ability to use any motor in the market without requiring it built as a special part of the tool enables the user to be independent of particular manufacturers, and gives him the benefit of great reductions in cost.

But in the case of some tools, and particularly large ones which have movable housings to which power must be supplied, the complicated system of belts, bevelled gears, spline shafts, loose pulleys, etc., relegated to oblivion by the attachment of a motor directly to the movable housing built to receive it, creates an advantage which is so obvious as to need only to be mentioned.

To illustrate a machine shop of the old type which we are now leaving behind us, and in which by the way is a large tool of the kind I have just referred to, I will throw upon the screen a view taken not long ago in one of our most important engineering works. You can see there is such a mass of overhead shafting and belting that cranes of any kind are precluded. You can also see how much moving mass there is, the function of which is solely intermediate between the power and its work, and you can see how, by the saving of this overhead gear, a large contribution is made toward offsetting the somewhat greater cost of electrical driving; and it is also not hard to imagine how, with the more compact arrangement of tools and the more perfect facilities for cranes and the handling of their work, together with the greater light and other indirect advantages alluded to by the previous speakers, the Baldwin Locomotive Works has indeed been able to save from 20 to 25 per cent. of its pay-roll as just stated by Mr. Vauclain, and how their floor space would have to be increased 40 per cent. were they to-day to abandon the electric power distribution which he has introduced. Such testimony from so eminent an authority is of the greatest weight, although the savings to which he has referred are not as large as some I know of.

Mr. W. H. Tapley:—The general and various advantages of the use of electric power in workshops have been so clearly and ably presented to you by the first speaker of the evening, Professor Crocker, that I will confine my remarks to the results we have obtained by the use of electric power

transmission in the Government Printing Office during the past five years.

Our electric equipment consists of:

GENERATORS.

One 300-K. W. Crocker-Wheeler direct connected to Allis Corliss Engine 16 × 30 × 30; speed, 150 revolutions per minute.
One 125-K. W. Crocker-Wheeler direct connected to Allis Corliss Engine 10 × 19 × 30; speed, 150 revolutions per minute.
One 187-K. W. Westinghouse kodak.

612 K. W., or a total of 816 electrical horse-power in station.

MOTOR EQUIPMENT.

		Horse-power.
Belted motors	21	167
Direct connected	22	105
Geared motors	145	375
Elevators	8	127
Hoists	4	80
Total		854

LIGHTING.

Equivalent of 5,000 16 candle-power 50-watt lamps, or 335 electrical horse-power.

HEATING.

		Ampères.
10 press heads:	Starting current	300
	Average running current	70

Average demand for power when everything is in use is about 1,500 ampères × 120 volts = 180 kilowatts = 240 electrical horse-power. This fluctuates between 1,000 and 2,000 ampères, or with a maximum demand of 240 kilowatts, or 320 electrical horse-power, this makes a ratio of electrical horse-power, connected to that called for, of 854 to 320, or 2·67 to 1 for maximum peaks and 3·5 to 1 under average running conditions.

So far, it has not been necessary to have more than the 300-kilowatt generator in service at one time to take care of both lighting and power combined.

Hours in service 1899, 300 kilowatt generator, 2,466.

Hours in service 1899, 125 kilowatt generator, 5,616.

Success of Electric Motors.—The use of electric motors has proven beyond a question of a doubt that they are economi-

cal and absolutely reliable under all conditions when properly designed and installed to meet the work required of them. This success is dependent on the fulfilment of all the details, such us a high grade of wiring, which means good insulation with a substantial protection from mechanical injury. The accessories should be of sufficient size to perform their work satisfactorily, the use of 230 and 500-volt starting-boxes and controllers of equal horse-power should not be used on 115-volt circuits at the same rating, as the increased ampères required by the lower voltage calls for more copper and larger contact surfaces, and unless this is given careful attention, failure will be the result, where it should have been success had these points been taken into consideration.

My experience has been, after an uninterrupted use of circuit breakers for five years on all classes of work connected with our office, that they not only protect the motor, but also the machinery, at the same time keeping down the heavy fluctuations upon the station necessarily resultant from ordinary fuse protection.

Cost of Plant.—Our electric plant consisting of power-house, generators, engines, switchboard complete, including circuit breakers on all feeder circuits, wire in main office and all feeder cables, electric elevators, electric motor equipment with labor and material used in changing from belt to direct connected electric drive, inclusive of lost product of machinery during alterations, cost $150,000.

Cost of Operation.—The amount of help necessary to operate our power plant has been reduced by two engineers over the old belt drive when we operated two engines for power and one for a small electric lighting plant; then, we only ran nights during a session of Congress, while at present our electric plant is in continuous service throughout the year.

The year 1894 being the last before the introduction of electric power, a comparative statement of cost of coal and gas for that year and the last fiscal year, *i. e.*, 1899, shows very clearly for itself a few of the benefits of the electric drive.

	Coal.	Gas.	Total.
1894	$18,284 00	$9,527 13	$27,811 13
1899	4,667 15	947 60	5,614 75
Difference	$13,616 85	$8,579 53	$22,196 38

Electric output during 1894 (lighting only), 218,175 kilowatt hours, as against 644,504 kilowatt hours in 1899 for both lighting and power.

During 1899 the boilers were called upon to heat 1,000,000 cubic feet more of space than in 1894.

The demand for power has more than doubled since 1894.

These results show, since the introduction of electric power, that the cost of help in power plant has not been increased, but slightly reduced, the coal and gas bills have been reduced a total of $22,196.38, notwithstanding the fact that the electric power plant has been called upon to furnish at least 100 per cent. increase of power for mechanical use in the office over the old steam plant, and the incandescent lamps have been increased from 2,000 to 5,000 16 candle-power, and the boilers were called to heat some 1,000,000 cubic feet more of space than in 1894.

The material increase in growth of the office has been close to 25 per cent.; this would mean an increased gas bill in 1899 over that of 1894, together with increased coal bill to safely permit the saving to be increased to a total of $25,000.00.

Our total outlay for the entire electric equipment, previously mentioned, was $150,000. This shows an earning of $16\frac{2}{3}$ per cent. on investment, minus $6\frac{2}{3}$ per cent. for insurance, taxes and interest, or a clear gain of 10 per cent. on total expenditures from coal and gas bills alone.

This saving directly in coal and gas bills, although considerable, is not the greatest benefit gained from the use of electric power in the Government Printing Office.

Our office has been crowded and overtaxed, all the machinery had to be practically placed in the H Street wing, which was the weakest portion of the building, with a resultant congestion of work that caused delay, and owing

to the disadvantage of handling it, the cost was usually necessarily higher than if they had not been so crowded.

The ability to arrange machinery irrespective of line shaft obtainable under the electric drive made all space equally available and valuable for all classes of work, and not confined to storage as heretofore.

This allowed us to add forty printing presses, which could not be accommodated in our old pressroom, and, although it did not increase the actual floor area, it did materially increase our working floor space.

The individual electric drive most unquestionably increased the output of our printing presses. The foreman of the pressroom told me that during installation he obtained 15 per cent. more work out of his room for the year than under the old belt drive, and that the coming year he expected to get an increase of 20 per cent., if not more. This is not bad from a man convinced almost against himself, having been opposed to trying electric drive, "as it was impossible to make it work as well as steam."

A conservative estimate will allow 10 per cent. as the increase in production from presses after change to electric drive.

The average earning capacity of our presses was $10 each per diem × 100 presses, $1,000; $1,000 × 300 days, $300,000; 10 per cent., $30,000, as a figure that can be placed as a sinking fund to pay for the equipment which, at this rate, should pay for entire electric plant in five years.

The other branches of our work will not show so marked a gain in increased production per capita as the presswork, yet we have been able to increase the output not less than 15 per cent. to 20 per cent. per square foot, with same help, in the mechanical divisions.

This amounts to considerably more than the cost of upkeep and general maintenance of the electric system, which during 1899 was $7,100.

These figures, I feel sure, permit our office to safely say that the benefits derived during the five years that we have been using electric power have financially purchased our entire electrical equipment and maintained it during this

period, and the saving in coal and gas has been paying 10 per cent. on investment after making an allowance of 6·6 per cent. for insurance, taxes and interest.

While our plant may not be as good as if everything were new, the increased cost of material since our purchases were made is more than I would feel justified in working off against the column of depreciation.

Coal consumption, 1899, 2,525 gross tons, which is equivalent to 8·78 pounds coal per kilowatt hour for all coal used in the entire building for heating (4,000,000 cubic feet of space) and manufacturing purposes, in addition to that used in electric plant.

During the months of February, March and April, 1898, we made a test of electric plant isolated from the heating and manufacturing, which resulted as follows:

1898.	Electric Output, Kilowatt Hours.	Coal, Tons.	Lbs. Coal per K. W. H.	Cost K. W. H. at Switchboard.	Total Cost of All Branches Electric Plant.
February.	59,909	81·6	3·05	$0.0206	$2,426.02
March.	69,990	98·3	3·14	.0203	3,286.66
April.	63,663	94·0	3·30	.022	2,564.00
1899.			This includes Heating and Manufacturing.		
January to December.	644,504	2,525·9	8·78	.0295	32,979.18

We find that it is more economical in the boiler house to operate the entire steam plant as a unit and not disconnect the electric plant.

Periodical checks are made on the electric system alone, yet the running daily commercial test gives us this within a small percentage.

With reference to the cost of current per kilowatt hour, I wish to call attention to the fact that all nightwork receives an increased compensation of 20 per cent. from day labor, all holidays men are allowed double time, and each man is given thirty days leave of absence with pay during the year. All these labor charges are included in the above table.

MR. W. C. L. EGLIN:—I have listened this evening with pleasure to the many testimonials from users of motors in large numbers, and the many advantages and economies to be gained by their use, so that any remarks from me on this subject would be but a repetition of the experiences of some of the other gentlemen who have just spoken. I will, therefore, confine my remarks more particularly to the installation of motors.

The motors made by the leading manufacturers to-day are very much improved, from a mechanical standpoint, from those with which Mr. Vauclain had so much trouble ten years ago. This is well borne out by the fact that in the Baldwin Locomotive Works one and one-third men take care of all their motors to-day, and, as they have motors of a number of manufacturers, it is now fair to assume that electric motors require less attention than any other form of motor. And, although it is true that the motor has been materially improved, the auxiliaries used in connection with the motor have not advanced with the same progress.

The flimsy construction of the switches, starting boxes and the cutouts, which are in many cases installed to-day, are invariably the cause of many interruptions of service for which the motor is in no way responsible. The arrangement of the wiring is a matter which should be given more careful attention.

With the increase of the size of the individual motors which are now being used, much more satisfactory service could be obtained by the use of a circuit-breaker instead of a fuse.

Personally, I feel that motors should be supplied with controlling equipments similar to those which are used for elevator motors, not necessarily so complicated, as the majority of motors do not have to reverse in speed.

The point which I wish to express is that all the auxiliaries necessary for the operation of the motor should be arranged in a compact form and enclosed firmly in an iron box, the operation of starting and stopping the motor being controlled by a single lever. This controlling lever should be provided with stops so that the motor could not be acci-

dentally started or stopped. In the design of these auxiliaries sufficient material should be employed to make them substantial and able to stand the hard use or abuse which they may receive in practice.

There should be no exposed metal parts carrying current. Provision should also be made so that the conduits will terminate in the controller.

The wires between the motor and the controller should preferably be placed in iron-armored conduit. This iron-armored conduit can now be obtained in a flexible form especially suitable for this class of work.

The increased cost of substantial equipment will be balanced by improved service and reduced cost of maintenance.

I feel that this part of the plant has been the one which has been the most neglected, but which is equally as important as good electrical and mechanical design of the motors.

MR. C. J. DOUGHERTY:—Replying to Mr. Eglin's inquiry in regard to the Greenfield flexible conduit, I wish to say that I have experimented somewhat with this conduit.

I took a sample piece of conduit which contained a twisted pair of No. 16 B & S. gauge wires, and subjected this to rough usage, and also made a test for insulation on the wire after the whole thing had been submerged in water for about forty-eight hours.

I found that the insulation resistance was quite high, and where wire is subjected to a great deal of hard usage, consider that this wire and flexible tubing is a very good article.

We are thinking very seriously of adopting this tube and wire for portable connections in our new machine shop at Cramps' Ship Yard.

Now, in regard to the subject of electrically driven tools, I wish to say that the tool maker and the manufacturer of the electric motor should consult each other in regard to just what they want.

My experience has been that the tool maker in many instances does not fully appreciate the conditions which he desires the motor to fulfil. I make special reference to

tools which are run by compound wound motors. Take, for instance, the case of punches and shears driven by electric motors. When the work is light, the number of punches per minute will exceed the maximum number of punches as specified. When the work is of a heavy character, the number of punches per minute will be about correct.

The tool maker, however, does not consider that there is a considerable variation in speed with the compound wound motor, and that he should distinctly specify what is the average horse-power required of the tool for work done. The tool maker considers that, if he specifies a motor of say 1,050 revolutions, no matter what the horse-power may be, he will still get the 1,050 revolutions irrespective of the power developed. But if sufficient information is given to the maker of the motor, it can be designed to fulfil in every respect all requirements.

DR. A. E. KENNELLY:—There is scarcely a direction of electrical engineering in which there is more scope for careful consideration and good judgment than in the installation of electric motors for driving machinery. There may be special cases in which it may be best to retain the ordinary line shafting and belting. In the majority of instances it will pay to introduce electric motors to some extent at least, and the least first cost consistent with the results desired may in many cases be obtained by the group system, with divided shafting and a motor on each length of shaft. Where, however, the best results of each tool are to be obtained, together with the other advantages incidental to electric driving, the principle may be advantageously carried to its fullest extent, and it may then pay to employ a separate motor for each machine. Every case should be studied upon its own merits and with reference to the character of the work and its output. It would seem, however, that in order to develop the best capabilities of modern machinery, makers of machinery are gradually leaning to the constructions which involve individual direct connection with electric motors.

MR. CARL HERING:—The time which is left is too short to say what I would like to have said in favor of the use of

electric motors for the distribution of power in workshops. I will therefore limit myself to a few words concerning the use of the multiphase induction motor, that is, the non-synchronous alternating current motor, for such work. The induction motor, formerly known as the Tesla motor, has, as is well known, no commutator, brushes, brush holders, etc., and therefore there is no sparking; it is extremely simple in construction, is not liable to get out of order, and requires no attention except oiling. It is easily started with full load, the larger ones requiring for this purpose some simple slide rings, at which, however, there is no commutation and therefore no sparking. It runs at nearly constant speed, and can stand considerable overload. It appears to be an important step toward the ideal motor for use in workshops where it is often put in out-of-the-way places and is taken care of by men who are as a rule not electricians. In a few cases its constant speed is an objection, as for crane work for instance, there being as yet no satisfactory method in use for varying its speed without impairing the efficiency; but such cases are the exception, and the induction motor is in that respect like a line of shafting, which also runs at constant speed, or is supposed to do so.

The ideal workshop system would be to have a motor for each tool or machine, but this is expensive on account of the cost of the motors and of their attendance and repairs. The induction motor goes a step farther toward this ideal than the continuous current motor, as it seems to be smaller, lighter, simpler and cheaper, for the same output and speed, than its rival.

While in Europe this summer I noticed the great progress that has been made there in the introduction of this type of motor. The largest electrical factory in Germany, and perhaps in the world, is equipped entirely with them, and mostly with a motor for each machine or tool. Even the rolling mills of that factory are driven with induction motors. Moreover, the three-phase system as distinguished from the two-phase, is used almost entirely there, especially in Germany and Switzerland. A single textile factory in

Switzerland has 500 such motors. Even some railroads in Switzerland are operated with them.

Mr. Dunn:—As this meeting is for the purpose of a discussion of the subjects involved in factory distribution of power, I feel that I would be in the position of assenting to the remarks of my friend Mr. Hering on the superiority of induction motors for factory distribution purposes did I not make some reply.

Contrary to Mr. Hering's view, I consider that so far for factory distribution the direct current motor possesses many advantages over the alternating. For instance, one of the principal requirements of machine shop work is adjustability of speed; in fact, it is to the facility with which electrical motors permit this adjustment that many of the enormous savings we have been discussing are due. It is also a fact that this, in particular, has not yet been accomplished by induction motors. To be on a par with direct current motors in the enjoyment of variability of speed, the frequency of the current as well as the voltage supplied to them would have to vary, since in an induction motor frequency and not voltage controls the speed. Varying the frequency of an alternating current system is impracticable.

Again, the starting torques of induction motors are much less than those of direct current machines, and in such service as crane work and similar kinds of duty, very large starting torques are requisite. Ordinary constant speed induction motors of the kinds built in this country do not develop, at starting, more than from 1½ to 2·2 their normal running torque, whereas direct current motors will easily develop in starting from four to six times their normal running torque. Of this point corroboration may be seen in most recent practice. Plants which have installed alternating current distributions have been obliged also to install alongside of them direct current distributions for the proper handling of cranes and similar machinery.

In spite of the enormous inducements for the employment of alternating motors for railway work, they have been unable to gain a foothold, because of their inadequacy

for the service demanded. It is true, as Mr. Hering has said, that in Europe induction motors are used much more widely than direct current machines, but I have always attributed this to the fact that the direct current motor in Europe was never so well developed as in this country, and consequently has suffered in comparison. The reason for this imperfect development is the custom abroad of building, rather than manufacturing. There, few motors are built alike. Engineers' specifications control the details for almost every plant, and interchangeability or uniformity of type is practically unknown. As a result of building machines by the half dozen instead of by the hundred or thousand, and of the continual changing of designs at the behest of every purchaser according to the often fanciful ideas of his engineer, there have not been evolved such simple and perfect types as this country has produced. I am informed, however, by one who has just returned from abroad, that in England the improvement in direct current motor building, resulting partly from the competition of the American market and partly from the recognition of the great advantages direct current motors possess, is causing a change of opinion as to the relative values of the two motors, and the use of direct current is greatly increasing.

Regarding the question of cost, and Mr. Hering's statement that induction motors are cheaper, I can only call attention to the fact that recent prices actually quoted in this country have been about 25 per cent. higher when the distribution was by alternating current. This difference in price is not due to variations between bidders, since the quotations are from individual companies which make both kinds of apparatus.

The induction motor has advantages in the absence of the commutator and the consequent care that this requires, but the direct current motors of to-day are vastly improved over those of but a few years ago. Great progress has been made without attracting very much attention, since the most prominent engineers have been giving their time to the interesting problems of alternating current. Commutators are made now that will run with but $\frac{1}{64}$ of an inch wear

per year, served by carbon brushes that will operate with a wear of from $\frac{1}{32}$ to $\frac{3}{8}$ of an inch per year, which brings them in point of attention required very close to the commutatorless induction motor.

On the other hand, the extremely small air gaps of the induction motors requisite for the keeping down of the power factor or wattless currents lead them into serious troubles, such as stalling by accumulation of dust and dirt, the overheating of the bearings and even occasionally the bending of shafts by unbalanced magnetic pulls occurring from slight eccentricities, the result of wear or other causes. The induction motor also requires enormous starting currents. I know of a case where the disturbance to the system from this cause is so great that an annunciator has been put in the engine-room with communication to and from each of the motors, so that only one motor may be started at a time on receipt of an answering signal and that the attendant in the engine-room may be advised to "stand by." The torque of an induction motor reduces as the square of the voltage, consequently fluctuations in voltage of the circuits are liable to cause fully loaded motors to fall out of step and stop.

A man connected with an important mining company in the Rocky Mountains supplied with power by one of the well-known alternating current distribution systems in that territory, recently informed me that his company was on the point of throwing out their induction motors, because of the stopping and burning out which occurred from fluctuations of voltage. In mine work copper is not liberally used, making the line losses large. In view of the fact that a 15 per cent. drop of voltage would cause a reduction of torque in the motor of nearly 30 per cent., it is not difficult to understand how a sudden fluctuation of this amount, caused by the starting of some neighboring motor, would cause a motor to lose its grip and stop.

Direct current motors do not take abnormal currents in starting, nor are they affected by wide or sudden variations in voltage.

I do not wish to be understood as pitting alternating

against direct current systems. The day has gone by when such antagonism existed, and now both methods go hand in hand for the accomplishment of a common purpose. I do maintain, however, that for the particular problems of workshop distribution distinguished from transmission and certain kinds of general distribution, the direct current system is preferable for the reasons I have mentioned and for others which there has not been time to discuss.

MR. HERING:—I regret that it is too late to reply as fully as would like to the remarks of my friend Mr. Dunn, who has done such creditable work in building continuous current motors and whose authority on these motors I do not question. He may be right in claiming that the continuous current motor has been developed to greater perfection here than abroad, but on the other hand, it seems, from the statements he made about the induction motors, that the latter are developed to greater perfection abroad than here.

I have already admitted that the constancy of speed is sometimes a drawback, but I still claim that such cases are the exception; it is one of the reasons why it is not so well suited for traction in cities. What I said about the relative costs, weight, etc., was based on statements of a manufacturing company in Germany which makes both kinds. The cosine of the angle of lag of their motors is over 0·9 and the wattless current therefore is not great. Moreover, they will stand 200 per cent. overload and still give their normal output for two-thirds the normal voltage. As for the starting current, I have no data at hand, but I saw some large induction railway motors started with a train of cars and my recollection was that the starting current did not exceed the normal, in fact I think the rule of the motorman was to cut out the starting resistance so as to keep the current about normal.

Mr. Dunn stated that his motors would start with six times normal torque. I doubt whether he or any other maker of continuous current motors would care to have their motors started in practice with such a torque; nor would the circuit breakers or fuses be likely to allow it.

ELECTRICAL SECTION.

Stated Meeting, held Tuesday, January 23, 1900.

ELECTRICAL APPARATUS IN COAL MINING.

BY JOHN PRICE JACKSON,
Member of the Institute.

The following paper is intended to give a description of the most important machinery that has been developed by the possibility of using electric power in mines, that is, electric locomotion, cutters and drills. Other apparatus will be merely touched upon.*

Uses to Which Electricity May be Put.—Electricity may economically be utilized in coal mining for lighting, hoisting purposes, pumping, cutting, drilling, running fans, operating breakers or washers, propelling bucket or belt lifts, driving repair shop apparatus, etc. The question as to whether any or all of these applications shall be used is dependent directly upon local conditions. If a system of mines owned by one company are supplied from a central power-house, it is clearly possible to do without local steam plants entirely at the individual mines. Such an arrangement has several advantages: (1) in the matter of economy of fuel; (2) the very great economy in repairs, and (3) a still further economy in working speed efficiency.

Types of Mines.—In dealing with the application of electricity to mining there are several types of workings between which a distinction may well be made. Probably the simplest form will be where the coal lies near the surface, and may therefore be obtained by means of stripping or open workings. In such mines electric drills can be used to great advantage, and electric shovels and cranes will also serve a valuable purpose in getting out the loosened material and loading the cars. If electricity is used for these purposes it may also be economically used for haulage from

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* For the illustration of the paper the writer is much indebted to the Jeffery Manufacturing Company for a very complete set of slides.

the mines to the dumps or washers in preference to steam locomotion.

The next class in order of simplicity is where the mineral lies in an approximately level vein appearing on the hill. side. In this case a drift or tunnel is run in, and by a system of headers or hallways access may then be readily made to all parts. Such a mine lends itself to the application of electric haulage with unusual ease. Electric drills may here be made of use and also under cutters, shearing machines, etc., if the coal is soft, as in the case of bituminous coal mines.

In the third class it is necessary to use a slope or shaft in order to reach the workings. In this case, in addition to the apparatus which was suggested for the drift, hoisting machinery may also be applied economically. Probably the most difficult variation of the third class is where the vein has a large dip or is badly broken up; under such circumstances the usual method is to run the gangway horizontally at right angles to the vein at the lowest point of the workings. These mines are then worked from the gangway upwards, the loaded cars pulling the empties up the inside planes from the gangway by means of gravity. Such a mine could use electric power for these internal planes to great advantage where the weight of the loaded car cannot be utilized.

The Effect of Number of Openings and Rapidity of Working upon the Efficiency.—In the case of an open mine where the vein is readily accessible, the number of openings is a matter of small moment, but where an expensive shaft, slope or tunnel must be driven before the vein can be worked, methods of reducing the number of openings to a minimum are of great importance when economy of operation is considered. If mules are used for haulage, the length of the gangway from a single opening cannot economically be made more than 1 or 2 miles. This is on account of the large number of mules that would be required to do the work for greater distances. If electric traction be applied, however, the high speed that can be attained and the large loads that may be hauled by a single locomotive render it

possible to extend the gangway to a length of from 4 to 6 or even more miles. Another equally important feature in the working of a great many mines is the rapidity with which the mineral can be taken out. To this result electric haulage lends itself with especially great success. In fact, the length to which a single opening may be extended, even for the most rapid working, where electric haulage is used, is determined almost entirely by the question of its maintenance. In some mines, especially in the anthracite coal regions, the length of gangways cannot be extended indefinitely on account of the large expense in keeping them up. The great natural pressure exerted makes it necessary to heavily timber the passages and also to continually get out material which is forced up from the bottom, and therefore tends to fill the passage.

Electric drills and cutters, as well as pumps, also do much toward the possibility of getting out material rapidly. The number of hand miners in a mine may be multiplied as much as possible, but this will fall far short in output rate compared with a mine of the same size utilizing electrical mining machinery so far as can be done.

Location of Station and Character of Power.—In coal mining the power used for driving the generators will naturally be steam. If a single mine with one opening is operated, the station should be ordinarily located in proximity to the shaft or slope. In this case steam engines may suitably be used for all outside hoisting or elevating purposes, while electricity is employed for all interior mining work. If, as is usually the case, several mines are operated by the same company covering a comparatively large territory, in many instances the most economical arrangement is to locate the power plant at a central position and then distribute electricity, as said before, to a sub-station at each mine opening, which should supply power for all purposes. There is likely to be great economy in such an arrangement, as it permits the centralization of all steam apparatus with a consequent rise in efficiency. In fact, when it comes to actual annual expense in repairs, fuel and cost of attendance, the electrical hoisting apparatus is superior even where the boiler and

engine house are located directly at the mine opening. The local conditions must be carefully studied, however, before the most economical arrangements of the power houses can be determined.

Systems for the Application of Power.—There are two methods of employing electric power in mining, as follows:

(*a*) Direct currents for all power and lighting purposes.

(*b*) Direct currents for haulage and polyphase currents for all other power.

The use of direct current machinery for pumps, fans and cutters has not been found satisfactory in many instances. One of the largest companies operating in the soft coal regions of Pennsylvania, after a thorough trial of such apparatus, rejected it in favor of compressed air. The machinery in a mine is subject to only rare inspection, and that oftentimes by unskilled workmen. The location of the machinery is likely to be the worst possible with respect to water, dust and chemical corrosion. In many cases pumps must be so located that it is impossible to prevent roof drippings from falling upon them. Such drippings are full of impurities, both in solution and granular, of a detrimental character. In fact, the water in a large majority of coal mines contains so much free sulphuric acid as to make it exceedingly destructive to the metal parts of a machine. Such conditions will readily cause electrical troubles in the commutator of the most carefully constructed motor. In so much as the stopping of a pump or fan even for a short time may cause excessive danger or expense, the use of an unstable motor is a serious menace.

Reasons for Installing Electricity.—The uses to which electricity can be put have already been summarized. The reasons for displacing other systems by this form of power are more or less apparent; for instance, the use of mules for hauling wagons from the chambers to the main gangways will probably always be desirable, and in case of mines covering a limited area it might in some instances be undesirable to undertake the expense of installing electric locomotives. But where the main gangway running from the workings to the shaft or slope is more than a mile in length,

the inefficiency of the mule becomes very striking. Mules, with a given number of openings, cannot pull out more than from a third to a half as much total load as can be done by means of electricity. If an endeavor were made to do as large a daily duty, the number of mule trains would become so great as to be entirely unmanageable.

A large number of specific figures from mines which have adopted electric haulage show an average saving over mules of from 5 to 9 cents per ton.

Experience has shown rope haulage to be much inferior to electricity in point of economy, as is now being illustrated by the continual substitution of the latter for the former. The cost of keeping the cable, shives and auxiliary apparatus in repair is an important item of working expense. The actual power required is also much in excess of that called for by electric haulage, and in addition the liability of a breakdown is great. The latter fault is one which will be avoided with the utmost care by a careful operator as it may entail serious expense. In one mine having an output of about 550 tons per day the saving over rope by the substitution of electricity amounted to from 5 to 7 cents per ton. This may be accepted as a fair average.

Compressed air locomotives are being looked upon with some favor by many mining interests, and it must be admitted that there are a number of features in their favor. As such locomotives carry their driving energy stored up upon their own trucks, they obviate the necessity for stringing wires. Moreover, they are not complicated in their mechanism or especially liable to get out of order. On the other hand, machines of this type must be charged each trip or at least at frequent intervals, which consumes time and is more or less cumbersome. They have a decided disadvantage in being of great bulk when constructed for heavy work and also in not having the capability for the high maximum torque which is one of the natural characteristics of the electric motor. Looking at all sides of the question it may be safely said that if electricity is used for other purposes in the mine, electric haulage will be prefer-

able to compressed air, and indeed will usually be the more satisfactory even when compressed air is installed for other work.

For mining pumps, fans, drills, cutters, etc., electricity has to compete with steam and compressed air. The first of these competitors has a firm foothold in the anthracite regions of Pennsylvania. Changes in this region are apt to be very slow on account of the conservatism of the operators. This inertia is sometimes due to lack of the capital required to make radical improvements in the plant, but more often to lack of information concerning improved methods. Probably the most important objection to the use of steam is the rapid deterioration of the timbers near which the pipes pass. The frequent heating and cooling of the damp timbers cause changes in the amount of moisture contained in the wood, which in turn results in quick decay. The piping with its proper covering is expensive, difficult to install, and can only be kept in good condition by constant attention. If the lines are long they are a source of large power loss by radiation and condensation, even when well covered. They are also frequently a nuisance in mines because of their high temperature. Steam engines and pumps are much more expensive than suitable electric apparatus from a standpoint of repairs and attention. Steam cutting and drilling, in most cases, proves unwieldy, since it is difficult to get rid of the exhaust, the difficulty in handling the hot apparatus, and also from the fact that covered steam lines run so far from the shaft, as the workings usually are, would be unwise. For the latter reason power pumps cannot be driven by steam at a very great distance from the openings, which frequently necessitates hauling out the water by mule power. To do this wagons are fitted with water-tight covers, hauled to the "sump," filled by buckets and pulled to the proper point by a team of two or more mules. The slowness and expense of such an operation is self-evident.

The second competitor of electricity, compressed air, is in many respects a much more serious rival. The mechanism of such apparatus is simple and requires little skilled

attention. The repairs and first cost are not great. Moreover, the elements of loss due to radiation and undesirable heat in the mine are absent. But this system, as in the case of steam, requires a large network of pipes. In order to use cutters, drills and pumps, this network must extend from the compressor plant to all parts of the workings. Whenever a section of the mine has been worked out pipes must be relaid to the new sections that are to be opened. The most serious objection to compressed air lies in the fact of its immobility for such changes. In the first place, the cost and trouble experienced in laying the pipe line may be estimated fairly as double that required for stringing wires, and in the second place, after pipes have once been used in a given location and are torn up, they are ordinarily only fit for the scrap heap. This is due to the fact already stated, that the moisture in mines contains much free acid, which will readily attack iron. The effect of this acid is such that when the pipes are torn up they are apt to be found with their threadings completely destroyed, and to be more or less honeycombed and rotten throughout. A compressed air plant must be continually putting in new materials for line work, while in the case of an electric plant the copper wiring may be used over and over indefinitely. The efficiency of compressed air systems from the standpoint of fuel consumption is comparatively low, and, although this may not be a very important matter in coal mining, it should not be overlooked. Still further, though as has been said compressed air machinery is simple and durable, it cannot be compared in these qualities with a well-designed induction motor. The system not being flexible makes it rather undesirable where rapid changes in the points of application require machinery which can be quickly transported or be made to meet a great variety of conditions.

Desirable Pressure to be Employed and Character of Wire Insulation.—Probably the first problem in the design for the electrical installation of a mine will be the determination of a suitable electric pressure. This is dependent upon the possibility of insulating the wires. Considering insulation first,

it may be said in general that it is impossible to put a coating upon the wires which can be depended upon to protect workmen or mules. All insulations that have been tried have sooner or later given out to such an extent as to render accidents liable. Probably the most suitable covering which can be given the wires is a triple braiding of cotton or linen thoroughly impregnated with an insulating weatherproof pitchy compound. After the wires are put up it is also desirable to paint them with two or three coats of this compound. This insulation cannot be depended upon to protect against accidents to life, but it is about the best for the use contemplated. Some mines are wired at least partially with heavy rubber-covered wire, but where the water is bad this is more or less wasteful in first cost, since wire of this character will deteriorate just about as rapidly as the former.

In determining what pressure is desirable it is wise to treat the question as if the wire had no covering at all. In one mine which came under the writer's notice a few months ago, four men were electrocuted within the space of a year, much to the consternation of the operators. The effect has been so great among the people of the region that it is thought not improbable that the system will have to be changed. In this particular mine direct currents of 500 volts pressure were used for haulage and three-phase alternating currents of the same pressure for all other power and lighting purposes. Three of the men were killed by contact with the alternating system, which had insulated wires throughout, and the other from the bare trolley. It has not been at all uncommon for men to be killed by contact with 500-volt trolleys, though ordinarily that voltage has not been considered fatal. At first these deaths were supposed to have been caused from previous heart troubles, but it is now generally accepted that if a man runs his head against the trolley wire while standing on wet rails, death is not unlikely to be the result. Those who have visited mines containing electric plants will appreciate how difficult it is to avoid the wires. The best possible protection must be afforded ignorant miners who cannot appreciate the danger.

With these considerations in view, it may be safely assumed that voltages of not over 250 should be used wherever the mines are not of so great extent as to make the cost of copper excessive, and that where the extent of mines requires 500 volts, special precautions should be taken to protect the workmen. Where alternating currents are used the amounts of power required are not apt to be nearly so great, as they will not be employed for haulage purposes. For this reason it should never be considered desirable to run the pressure above 250 volts. Another reason for this limitation for alternating currents is that they are much more deadly than direct currents of equal voltage. If higher alternating voltage is desirable, it may be transmitted over wires in airways to central points and then be reduced by means of transformers.

Mine Wiring.—It is desirable to next consider what special features are required in the interior wiring of the mines, as it is evident on even a casual thought that the conditions are radically different from those to be found outside. In nearly all mine work pockets of rocks from the roof are apt to fall and carry with them anything so slender as ordinary line work. (It might also be of interest to say in passing that this instability of the roof is the most serious danger to life in a great proportion of mines.) In shafts and slopes any uncovered wire is liable to injury, not only from the natural breaking away of walls, but from the many accidents which occur in regular service. In all parts of the mine the confining spaces, combined with the ignorant class of workmen usually employed, make accidents to the system of wiring, through mere carelessness, difficult to avoid. These considerations render it important that this part of the plant be put in very substantially and carefully. In spite of this, however, the matter has been sadly neglected in a large proportion of the types of plants we are considering. It is not uncommon to find wires thrown over a spike or nail for support, or to see them hooked together at joints in the most careless fashion and swinging loose as though they were clothes lines. Where the writer has visited such mines he has invariably found that the owners were not

greatly pleased with the use of electrical machinery. They said it was too liable to break down.

Trolleys for haulage are put up with much the same fixtures that are to be found in the ordinary overhead work, except that the insulator or switch ears are usually clamped to the wire instead of being soldered, so that the work may be readily torn down and rebuilt. The insulators are fastened to the timbering where possible by means of suitable top plates and lag screws, to iron pipe brackets driven into the wall when the height of roof will permit, or into the rock roof itself. In this last case one method for making the fastening is by using what is equivalent to a short piece of pipe split diagonally. A hole is driven into the roof and the bolt for supporting the insulator is inserted with the head up. The pieces of split pipe are now placed about this so that when they are pushed together endways they shove on their wedge sides and thus expanding take a close grip upon the sides of the hole. This method is also used for fastening the supports for ordinary line insulators. Sometimes wooden wedges are worked in much the same manner. The trolley wire should be arranged with switches every few hundred yards, so that sections can be cut off, when it is necessary to move mules from place to place, or for any other reason. These switches should be encased in weatherproof boxes. In one mine, where the mules stop work in the evening when the last locomotive starts out, the motorman cuts off each section as he goes out, thus permitting the mules to follow immediately. In the morning the mules start in first, and the following motorman cuts in the switches after them. Before the company adopted this scheme many mules were electrocuted, though the pressure was only 250 volts. The mine mule seems very susceptible to the influence of electricity. It would also be well at cross-overs and turnouts to have hanging guards which would warn the miners of danger.

The return circuit should be made just as substantially, by means of a proper bonding of the track, as would be done in a well-equipped passenger railway system. Where pipes run near the tracks they should be carefully connected

at short intervals to this return circuit by means of substantial copper wire taps. Failure to do this has caused the destruction of much piping, due to electrolytic action.

Feed wires are supported on porcelain insulation of the ordinary type if fastened to the wall; if fastened to the roof they should be especially arranged. In one form the moisture is drained down a pin and passes through a hole in its center to the bottom of the insulator, where it drops off, thus leaving a dry surface about the wire. Branches or sub-feeders should have cut-off switches and fuses. The wires should be run so far as possible in airways or abandoned gangways, under which circumstances both the wires and the miners are protected. When feeders run down shafts or slopes, or in places liable to disturbances, they should be put in strong iron-armored conduit. Wherever they are so placed as to cause dangers to workmen they should be sheathed either by wooden boxing or conduit.

Electric Locomotives.—Having now dealt at some length with the conditions to be met in utilizing electric mine power and the requisites for its distribution, we are ready to consider a few of the features of the machines that do the work. The electric locomotives used in mines are similar, in a general way, in their electric features of design and control to the equipments found in street railway service. They are much modified in detail, however, by the fact that they must be able to pass through gangways as low as 40 inches, must pull heavy loads, must withstand rough handling by unskilled labor, must run from very low to very high speed, and must be so arranged that the motorman has very ready control. The last condition is more important in mine work than in any other class of haulage, as the motor runs in locations where the track is liable to be obstructed at any time by falling rocks or a stray car. Since such obstructions, due to the numerous curves found in most gangways, will frequently not be seen until the motor is within a few feet, the necessity for quick and absolute control becomes obvious. The control depends upon three elements: the method of regulating the motor; the system of brakes; and the arrangement of controlling levers with

reference to the motorman's seat. Another subsidiary element, but in many ways vital, is the sand-box. As a rule much moisture is to be found in mines, and the rails are, therefore, exceptionally slippery. This condition evidently calls for efficient sand arrangements. Commonly four sand spouts are used, one for either track at both ends of the car.

Description of Locomotives.—The base upon which the mining locomotive is built is an exceedingly heavy iron frame containing supports for the wheel boxes, and extending downwards to within 4 or 5 inches of the track. In some locomotives the wheels are placed outside of their boxes and this frame; for ordinary practice they are within. The number of wheels is usually four, though at present a few large locomotives are being designed with three pairs. On two or three axles, as the case may be, are placed the motors. These motors are of the waterproof street railway type, and vary from 15 to 50 horse-power capacity each. They are supported at one end through bearings on the wheel axles, and at the other by means of suspension springs. Heavy brakes of the steam locomotive type are placed upon each of the wheels. Sand-boxes are arranged as already explained. A headlight is placed at each end of the frame, and both are expected to burn continuously when the locomotive is in operation. These headlights usually consist of a cast-iron box with reflector and protecting screen, and containing a sufficient number of incandescent lamps in series to use up the impressed pressure. The headlights should be on separate circuits. A better and far more efficient plan is to use enclosed arcs instead of incandescent lamps, with the proper amount of resistance in series. The added safety attained by the use of such a headlight will well repay the extra expense in power used. The controller is similar to the ordinary street car controller, except that the resistances are heavier to enable them to safely carry the excessive overloads which are frequently developed. This resistance, which is usually in the form of iron sheets with mica insulation, is packed away on the frame between the motors. The trolley wheel is of the ordinary type. The trolley pole is about 4 feet long, and is set in a socket at

either side of the locomotive, on a swivel, and is so arranged by springs that it will follow the trolley from 4 to 5 inches above the deck of the car to a vertical position. If the pole is of iron it should be thoroughly insulated, as it must be handled frequently by the motorman. The motorman's seat is usually placed at only one end, in which case the locomotive is called a "single-ender." Sometimes a seat is placed at each end or in the middle between the axles, which constitutes a "double-ender." The latter form is especially desirable, as the heavy frame surrounding the motorman protects him from accident. The brake-wheel should be placed conveniently to the motorman's right hand, the controller handle to his left, the sand-box lever to either hand or to the left foot, and the reversing and cut-out switches to the left hand. The proper arrangement of these details is of great importance to the success of the machine. The heavy frame and all the apparatus contained on it should be supported upon the wheel axle boxes through spiral or carriage springs. If this is not done efficiently the great weight of the locomotive will cause heavy track repairs by its severe pounding. The wiring, which is encased in strong canvas hose, must be supported firmly to prevent abrasion of the insulation. All levers or portions of the apparatus should be kept at least 6 inches above the level of the tracks, and should be protected by the apron of the heavy iron frame. All the apparatus should be closely covered to prevent the entrance of moisture and dirt. In doing this, however, provision must be made for the escape of heat from the rheostats.

The weights of locomotives vary from 4,000 to 30,000 or even 40,000 pounds. A 12,000-pound machine would have about the following proportions: draw-bar pull on the level, 1,500 pounds; speed, 6 to 10 miles per hour; two 20 horse-power motors; a minimum gauge of from 27 to 30 inches; minimum width over all, 48 to 50 inches; minimum height of from 36 to 40 inches; length, excluding bumpers, from 9 to 12 feet; wheel base, from 40 to 55 inches; diameter of wheels, from 28 to 30 inches. A 24,000-pound locomotive would have a draw-bar pull of about 4,500 pounds; 6 to 10

miles speed; two motors of 50 horse-power each; gauge of from 35 to 40 inches; outside width of from 58 to 65 inches; height of from 38 to 45 inches; total length of from 11 to 12 feet; wheel base length, from 40 to 56 inches; and diameter of wheel from 28 to 30 inches. The minimum weight of rails that can be used satisfactorily varies from 8 pounds per yard for a 2-ton locomotive to 40 pounds for the heaviest. Mines using from 12,000 to 16,000-pound machines should, under ordinary conditions, use about a 30-pound rail. Where exceptionally heavy service is encountered the adoption of 60-pound rails is meeting with favor. The draw-bar pulls are given for running on the level. On an up grade the pull will be reduced on account of the locomotive having to pull up its own weight. The element of the force of gravity tending to pull the car down hill, and which therefore must be overcome, is approximately one hundredth of the total weight for each per cent. grade. This would be equivalent to a draw-bar pull of 20 pounds per ton. In the case of the 12,000-pound locomotive given above the draw-bar pull on a 5 per cent. grade would thus be reduced from 1,500 to 900 pounds.

The Hauling Power of Locomotives.—The number of tons a locomotive can pull over a given maximum grade will be dependent largely upon the character of the wagons and the tracks. If the wagons have loose wheels on fixed axles and are in first-class condition, the actual friction per ton of gross weight may reach a minimum limit of 20 pounds, though even under these conditions 30 pounds will usually be nearer the correct figure to use. On the other hand, if the wagon wheel bearings are badly worn or the track is much out of alignment, the tractional coëfficient may reach even as high a figure as 70 or 80 pounds. To determine the size of locomotive required for a given mine, the first thing to be known is the maximum or limiting grade over which the load must be hauled. Next the tractional or frictional coëfficient must be determined as nearly as possible by inspection of the wagons and roadbed, or any other data available. If this coëfficient plus 20 pounds, multiplied by the per cent. grade, be divided into the loco-

motive draw-bar pull for the given grade, the result will be the number of gross tons that can be hauled in addition to the weight of the locomotive. For instance, suppose the 6-ton locomotive before considered is to operate in a mine having first-class track and cars and a maximum grade of 2 per cent. against the load. The draw-bar pull at this grade will be 1,260 pounds. The force to be exerted against the grade will be 40 pounds per ton, and that required to overcome friction 30 pounds, making a total resistance of 70 pounds per ton. This divided into 1,260 equals 18, or 18 gross tons can be hauled.

Electric Cutters.—Electric cutters are designed primarily to cut soft material such as bituminous coal, though it ought to be possible to modify them for satisfactory use in harder materials. The material on which these machines are used is seldom of a uniform nature, as the soft coal veins are more or less polluted by "clay" veins. These clay veins are extremely hard and difficult to cut. A machine to operate successfully under such conditions must be constructed with great mechanical rigidity; also the electric equipment and its control must be made to withstand extreme overloads and shocks. The cutter is usually designed to undercut the mineral vein and is then called an undercutter, though it is also made for a vertical cut, in which case it is called a shearing machine.

Chain and Bar Cutters.—The cutting may be accomplished in the chain machine by having a large number of blades attached to the periphery of a sprocket chain which revolves about a large sprocket at the cutting end of the machine. The chain is driven by another sprocket at the rear of the machine, which is connected, through a series of gear wheels, to the motor. This chain cutter system, with its motor complete, is arranged so that it will move forward 6 or 7 feet on the tracks of a base upon which it is mounted. The end of the chain which passes around the large wheel is so arranged that when the blades or cutters are pushed against a wall they will cut a clear path for the wheel, bearings, etc., to follow. The base upon which the cutter proper slides is braced firmly to the walls and the roof by

means of jacks. The relative speed of the feed along the tracks and of the chain cannot ordinarily be changed, but the positive speed of both should be controlled by a proper motor regulator, so that when the cutters are passing through different types of material suitable speeds may be maintained. The truck by which this motor is moved from room to room is specially constructed with rails and chain block, so that it may be loaded and unloaded readily. These trucks are sometimes also arranged so they may be geared up to the motor after it is loaded, thus making it self-propelling. Such an arrangement is highly advisable, as the apparatus is heavy and difficult to move by hand or mule power.

The direct current motor is not nearly so satisfactory for a machine of this type as is the alternating current induction motor. If used it should be of the shunt type and should be designed to stand an overload of 100 per cent. for short times without injury. The controller should be of heavy resistance, capable of withstanding an equal overload. Under no circumstance should a starting-box only be used. For starting polyphase induction motors the ordinary methods of changing the resistance in the armature or of using an auto-transformer in the fields are satisfactory.

To operate a chain undercutter the machine on its truck is hauled into the room on the wagon tracks and placed with its cutters next the face of coal to be cut, and on the left-hand side of the room. It is there run off its truck and jacked firmly in place. A fixible cable, almost 100 yards long, is used for connecting it with the mains. Two men are required, a runner and a helper. The runner has charge of the machine, starting and stopping it, and keeping it in good condition. The helper shovels back the cuttings, and assists in moving and jacking the machine. Having set up the machine, it should be able to make a cut about 6 feet deep and 45 inches wide, with a kerf of from $4\frac{1}{2}$ to $5\frac{1}{2}$ inches in from three to five minutes. When the machine has fed itself in to its full depth it either reverses itself or is reversed by hand. The time of withdrawal is about one minute. Having been withdrawn, the machine is moved over

and made ready for another cut. A cutter of this type should be able to cut from 100 to 300 linear feet of coal face per day, 6 feet in depth, the actual amount being determined by the seam and the number of moves that must be made.

The dimensions of a cutter of this type vary from about 18 to 30 inches in height over all, making a cut in width from 40 to 45 inches, and from 5 to 7 feet deep. The capacity of the motors used is from 8 to 16 horse-power. The low machines can be used in veins from 2 to 3 feet in thickness or higher. The great trouble with coal cutters in the past has been their mechanical construction. They have been found, in many instances, when striking a stiff clay vein, to so wedge into the kerf as to require digging out with a pick and shovel. The heavy service has frequently caused such great repairs and so many delays from mechanical breakages as to make the machines uneconomical. Also lack of stability and simplicity in the details of the electrical construction have caused serious annoyance and delay. These difficulties can be overcome.

Cutter-bar machines are similar in their general construction to the chain machines, except that the knives are placed on a horizontal bar, which rotates and cuts into the wall. The arrangement is a little like that of a wood planer. These machines are being superseded by the chain type, as they are apt to clog with the cuttings and in other ways are not as satisfactory.

Longwall Machines.—The longwall system is another method of machine mining. In this system one or two rails are laid along the coal face to be cut and the machine is fed along this by a suitable cable arrangement or gear and pinion. In this machine, instead of using a chain, the cutters are placed upon the periphery of a large wheel which extends out from the side of the base into the wall to be cut. The motor for this machine should be similar to those used in the machines just described, but should be of somewhat greater power—from 15 to 25 horse-power. The cutting wheels may be made to cut into the face to a depth of from 3 to 5 feet, making a kerf of from 4 to 5 inches. The

wheel must be arranged to deflect slightly on an axis at right angles to the wall, in order that it may take the variations of the bottom. These machines can be made to cut through soft coal at as high a rate as 25 inches per minute, but should have a variable feed speed so that the rate may be made as required by the character of the material cut. The feed rail must be firmly jacked between the roof and floor.

Shearing Machines.—Sometimes it is found desirable, on account of formations in the mines, to make a vertical instead of a horizontal cut. For this purpose a shearing machine is used. This machine is similar to the chain undercutter, except that the cutting chain runs in a vertical plane and can be raised or lowered to suit conditions. To provide suitable supports for holding the machine at any height on the vein, it is clamped to two or more rigid columns which are jacked between the roof and bottom. To make a cut, the machine is first placed at the top, and the cutters run to their depth; they are then withdrawn and the machine lowered for another cut. This is continued until the whole thickness of the vein has been sheared. The width of a cut is from 30 to 40 inches and the depth from 5 to 7 feet.

The chains and cutters of these various machines bear the largest strain and must therefore be given special attention. If the bits are permitted to grow dull, the machine may use from two to three times more power than necessary and will give great annoyance. The number of bits on a chain will vary from 35 to 50. The advantages of coal-cutting machines are about as follows: A saving in wages in mines of from one-fourth to one-half, or an increase in the output of the mines to the same extent; the total saving in the cost of mining and placing on car in mine room, nearly one-half of that required in pick mining; and an increase in lump coal of from 3 to 5 per cent.

Electric Drills.—Electric drills may be used in all mines whatever the material to be dealt with. If the material is very hard a reciprocating drill must be used, but for coal

mining an auger or rotary drill proves most efficient. This serves to displace the hand augers which have been used heretofore in blasting out the material. The motor must be of very light construction ; in fact, efficiency should be sacrificed to give the least possible weight in the design. From 1 to 1½ horse-power gives sufficient capacity. The construction must be as rigid as in the case of the cutters previously described. The mechanism may be divided into two types, that is, geared and direct-connected. In the former the motor is geared down to the natural speed of that of the drill, while in the latter the weight in the motor is sacrificed so that its armature can be mounted directly upon the spindle holding the bit. The former construction is the more complicated, but the latter is heavier. Under all circumstances the design should be so made that the complete apparatus can be readily handled by not more than two men. The motor with its spindle is so arranged that it can be clamped upon an upright post through the intermediary of a swivel joint, which will permit turning it at any angle. It must also be possible to move it up and down along the post, the two movements combining to make it applicable to any situation. Such a drill should be able to drill from six to eight times as rapidly as a man with a hand borer.

Electrical Pumps.—The remaining important classes of electrical apparatus used in coal mining, namely, pumps, hoisters and fans, are of the same general characteristics as are those to be found in other industries, so that we will only give them a cursory glance, pointing out a few important points. So far as possible in mining, the workings are arranged so as to permit the water to flow by gravity from the workings to the foot of the shaft, where, as a rule, it is pumped out by large steam apparatus. Insomuch as it is impossible to often run all the water by gravity to this point, a number of additional stationary pumps must be placed at various points. The latter must be of the compressed air or electric type, and if electricity is used, the former should also be driven by it. The objections to compressed air and steam have already been stated, but there is the added

objection to the steam shaft pump as frequently used in the low economy when compared with its brother, the electric power pump. There is another class of pumps which is strictly a mining type; this is the portable pump. In a mine of great extent there are apt to be numerous small pockets in which the water collects, but which are not important enough to call for the installation of a stationary pump. It is not uncommon, as has already been stated, to haul the water from these pockets in wagons. The portable pump has been developed to obviate the expense of such work. Such a piece of apparatus consists of a small duplex or triplex power pump driven by a small direct current or polyphase motor, and mounted upon an exceedingly rigid truck. The truck must be of such strong construction as to prevent serious vibration. In using such a pump the water is dammed up in unused gangways or other spaces, until quite a body has collected. The pump is then brought to that point and the water cleaned out. By this means a single pump may be readily used to keep a large area of the mine dry. A pump of this character connects to the power feeders by a coil of flexible wire, and carries its controller, switch, fuses, etc., on the truck. The truck itself may be made self-propelling, if a direct current motor is used, by the addition of a trolley pole. This is quite a convenience sometimes. The best form of pump for mining purposes in general is one of substantial horizontal duplex form. The vertical pumps, as a rule, are too scantily built, in order to make them of low enough height, to be satisfactory for such work. The motor should be of slow speed, with simple gear arrangements for driving the crank rod, preferably using a worm mechanism.

Electric Hoisters and Fans.—The hoisters for use in mines and driven by electricity are exactly like those for connection to a steam engine. In addition to the economy of the former over the latter, the one striking advantage is the possibility of using absolutely sure automatic braking devices. By means of a suitable solenoid attachment to the brake-band it is readily possible to have the brake go on whenever the current is off, whether due to broken con-

nection or regular service; also to have the brake automatically act when the speed exceeds a given maximum. The comparative efficiency of the steam hoisting engine as ordinarily used, and the electric motor supplied by a first-class generating plant, is well known to you all; the latter use from one-third to one-half as much energy as the former, if not less. In this particular application the direct current motor probably has a little advantage on account of its large torque when built of the series type, but the modern well-designed polyphase motor will meet requirements even in this regard, and has so many additional characteristics of stability as to make it superior.

The use of fans in mine is much facilitated by the application of electricity, since they can be placed all over the interior, as well as outside, with very little expense other than the original cost of the fan itself. Where electric power is not available it is frequently found necessary to use hand fans in some of the distant workings, or construct airways at excessive expense. These fans are of the regular ventilating type to be seen in any large building and need no description.

Suitable Superintendents.—Before closing, I wish to make one remark in regard to the present practice of employing engineers or superintendents for mining power plants. After a variety of experience in inspecting and testing a large number of equipments of this character, the writer has become convinced that mine operators must take a different step in reference to superintendence or they will lose much of the advantage of their plants. The ordinary method now is to break in some especially bright young miner, let him learn as he can some of the important duties required in taking care of such a plant, and then put him in charge with possibly a few other boys to help him. Such is not uncommonly the case where even as much as 500 to 1,000 kilowatts of electrical energy are installed. The salary paid is, of course, entirely too low to attract a properly trained man. The result of this saving in the superintendent has been much stoppage and consequent decrease in output, heavy repair bills and a rapidly

depreciating plant. It is fair to assume that this machinery, which is even more difficult to operate properly than a street railway or transmission plant on the surface, should have a thoroughly well trained electrical engineer at its head. If the mine owners of the country should heed this one suggestion practically all the difficulties now experienced in electric mining equipments would be abolished.

STATE COLLEGE, PENNSYLVANIA,
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CONCERNING RETENE, PETROLENE AND ASPHALTENE.

BY S. F. PECKHAM.

The persistent use of the word retene, or retine, and more especially of the words petrolene and asphaltene, in current literature relating to solid bitumens and bituminous minerals, leads me at this time to offer a protest against their further use, with reasons therefor somewhat *in extenso*.

The prominent position which Mr. Edward J. De Smedt has held in reference to asphalt paving in the United States has given his opinions great weight among those engaged in that industry. In 1893 he published in *Paving* a remarkable paper, which he said was designed "to open a discussion and investigation in regard to the required qualities of asphalt to form the best pavement." After making statements in reference to bitumens in general, he proceeded to make a few rather sweeping assertions, which may be carefully considered. He says: "Bitumens are generally composed of three different hydrocarbons: (1) retine, (2) petrolene, (3) asphaltene. The knowledge of these compounds is due to the important investigations of Messrs. Le Bel and Muntz." "Retine—C, 78·84; H, 10·22; S, 10·78—is soluble in alcohol; submitted to heat, it gives off hydrogen sulphuret, marcaptan, and liquid hydrocarbon,

and some coke is left. This compound is not desirable in asphalt.

"Petrolene—C, 80·60; H, 10·20; S, 9·20—is soluble in ether, and is the most important and desirable compound in asphalt for paving purposes, since it is the compound which gives the viscous adhesive qualities to asphalt.

"Asphaltene—C, 78·00; H, 8·83; S, 12·89—is not soluble in alcohol or ether, but is soluble in chloroform and in bisulphide of carbon. It is this compound which gives hardness to asphalt, and the more asphaltene an asphalt contains, the more brittle and hard it is. So an excess of asphaltene is detrimental in asphalt employed for paving purposes."[1]

As the technical considerations involved in De Smedt's paper were met in a masterly manner by Captain Dolphus Torrey in a paper published in *Paving* in March, 1894, I shall not further refer to that aspect of the subject. De Smedt was very unfortunate in his manner of conducting the discussion, and it soon fell for want of cohesion.

When De Smedt's paper was published, I was in California and was not reading *Paving*. I was, however, soon brought in contact with the practical effects of this publication. As chemist to the Union Oil Company, of California, I was asked to determine the amount of retene in their products, and in correspondence I began to receive memoranda of determinations of retene. The name retene had been for many years applied to a crystallizable body soluble in alcohol which was derived from several varieties of fossil resin. As it is crystallizable, its formula had been carefully determined to be $C_{18}H_{18}$ or some other multiple of CH. A great number and variety of different compounds derived from it had also been analyzed. There has been no question about the composition and relations of retene for years as described in the general and periodical literature of chemistry. When I was asked to determine the amount of retene in an asphaltic residuum from California petroleum, and learned that a great many determinations of retene were being reported as made from asphaltum from many localities in differ-

ent parts of the world, I began to wonder what had happened.

At last a prospective purchaser of California products requested us to ascertain the amount of objectionable retene contained in our material, and I set to work to make the determination. I had previously learned that methyl alcohol dissolves a certain percentage of our product, ethyl alcohol dissolves more, and amyl alcohol still more. By prolonged boiling in 95 per cent. ethyl alcohol nearly as large a percentage was dissolved as in ethyl ether or petroleum ether. No crystallizable body could be obtained from any of these solutions, and I discovered that by varying the strength of the alcohols and the temperature at which they acted, the proportion of the residuum dissolved could be varied indefinitely. Further experiments upon crude California and other asphaltums give similar results.

Later, I was asked by a friend, who was in correspondence with a chemist *in re* retene, or retine, I don't know which, if I had made any determinations of that constituent of asphalts. I related the facts as given above and suggested that the correspondent be asked, if he had obtained any crystallizable retene from any asphaltum, to tell how he did it. He replied that he had never determined retene, nor had he ever obtained a crystalline compound from any alcoholic solution of asphaltum. This experience confirms my own.

As to the word retine, I have made an exhaustive search of the dictionaries of several modern languages, as well as English, and can find only one word with that spelling. That is the French word which is equivalent to our word retina, as applied to the eye.

If I understand De Smedt, he refers to the researches of Le Bel and Muntz as his authority for what he says *in re* retene, or retine. I have never seen any memoir, by either or both of these gentlemen, wherein any reference is made to any such substance, or, in fact, to any alcoholic solution obtained from bitumen.

Captain Torrey has written quite *in extenso* upon the alcohol soluble from Trinidad pitch. All that he has pub-

lished upon the subject is to be found in *Paving*.[2] He has very carefully conducted a large number and variety of experiments upon this alcohol soluble. He has discovered and recognized the differences produced by varying the strength and temperature of the alcohol, and he seeks to counteract their disturbing influence by what he calls a *time limit*. He allows the alcohol to act in exact periods of time, which he seems to think will give exact results. I do not think he can escape the relations of strength and temperature in any such manner, nor do I see any occasion for it, unless the petroleum ether soluble can be divided by using absolute alcohol at some fixed temperature. What is wanted is an absolute factor that can be repeatedly determined in the same specimen within reasonable limits; or, in language lately used by Dr. S. P. Sadtler, "What is wanted is a study of the action of a series of solvents of fixed purity upon different natural bitumens."[3]

One curious practical illustration of the use which has been made of this name is found in an "Asphalt Hand-Book," issued by the Standard Asphalt Company, of California. Dr. F. Salathé made an examination of their crude asphalt, and finding that acetone would dissolve more of it than petroleum ether, he made an acetone soluble and called it "Petrolene (retenoid)." The portion insoluble in acetone he called "Asphaltene (retine)." He further gives the "combined sulphur (chemically held in bitumens)" as 0·73 per cent. What meaning did Dr. Salathé attach to the word "retine" as used here? De Smedt's retine had 10·78 per cent. of sulphur and his asphaltene has 12·89 per cent. Did he intend that these substances are practically identical? Moreover, De Smedt's petrolene has 9·20 per cent. of sulphur; therefore, according to De Smedt, the California asphaltum should contain:

			Per Cent.
Petrolene	67·50	Sulphur	6·21
Asphaltene	32·50	"	4·18
	100·00	"	10·39

Dr. Salathé reports the content of sulphur to be 0·73 per

cent. No more striking illustration can be found of the use of words that have no meaning.

So far as I am acquainted with the literature of asphaltum, it is not clear who first applied that name petrolene to that portion of asphaltum that may be soluble in ethyl ether or petroleum spirit. In the exhaustive work of Alfred H. Allen, upon "Commercial Organic Analysis" (Vol. II, page 374), published in 1886, mention is made of Boussingault's separation of asphaltum into "petrolene" and "asphaltene," but no further reference to the use of these names is made. It is possible that De Smedt first used that method of analysis and applied the names as they have since been used, but apparently we are indebted to Mr. Clifford Richardson for their use.

Their use has proceeded of late years upon a totally erroneous conception of the constitution of asphaltic minerals and their relation to each other. If the arbitrary use of these names had been confined to Trinidad pitch, and the method or procedure of analysis of which they form a means of expression had been confined to the admitted determinations of the location of the spot upon the Island of Trinidad from which any given specimen came, less confusion would have arisen than has followed the attempt to designate many different things by one name. In a general way, it may be correctly said that there are no two asphaltums from different, widely-separated localities that are alike. If the same proportion to a $\frac{1}{1000}$ of a per cent. is soluble in any of the solvents of bitumen, it does not establish the identity of the two specimens. There has been nothing approaching the exactness demanded in chemical science observed in the use of the word petrolene. Ethyl ether, petroleum ether and acetone have all been used as it suited the convenience of the experimenter, and the percentage dissolved has been called petrolene, and various assertions have been made concerning petrolene and the relative value of asphaltums containing much or less of it; when at the same time the material dissolved from one asphaltum is one thing, and that dissolved from another asphaltum is quite another thing, and the different proportions of material dis

solved from the same asphaltum by different menstrua are equally different. It is obvious that much that has been said in reference to petrolene applies with equal force to asphaltene. The names have been applied to various residues soluble and insoluble in various menstrua, and in various proportions. These residues possess various physical and chemical properties, and are in few respects identical. The name asphaltene has been used to designate that portion of Trinidad pitch that is alone soluble in carbon disulphide. Mr. Richardson admitted, in his testimony given in the Peoria trial, that carbon disulphide did not dissolve the bitumen in Trinidad pitch within 1 per cent., and Messrs. Wallace and Whinery, on the same occasion, described the material dissolved in this manner as an inert substance, without cohesion, and playing the same part in a paving cement as the same amount of sand.

I have found that if Trinidad pitch be first exhausted with petroleum ether and then with carbon disulphide, when the latter solution is evaporated there remains a brilliant black solid that cleaves from the vessel in thin scales. These scales are insoluble in petroleum ether, ethyl ether or alcohol, melted paraffine, and in fact most of the solvents of bitumen. They are wholly soluble in chloroform and benzole, and partially soluble in boiling spirits of turpentine, the portion insoluble appearing as a brown powder. If the scales are dissolved in benzole and petroleum ether added in large excess, a brown powder is precipitated that may be collected on a filter. When the powder is heated it becomes black and coheres. The portion soluble in spirits of turpentine may be wholly or partially precipitated, by an excess of petroleum ether, as a brown powder. When the solution of that portion soluble only in chloroform is evaporated and the residuum washed in ethyl alcohol, it appears as a brown powder without cohesion. These reactions show that the black scales obtained by the evaporation of the carbon disulphide solution above mentioned consist of a mixture of two, if not more, distinct substances. The first of these that is soluble in boiling spirits of turpentine is a very dense and exceedingly viscous fluid, possessed of great

tenacity, and it evidently plays a very important part in the cementing properties of Trinidad pitch. The portion that is only soluble in chloroform is a dark brown powder without cohesion, that does not melt when heated, but softens, becomes black, and at a red heat is decomposed, giving off a white vapor which takes fire and burns, leaving a carbonaceous residue that continues to burn at a red heat, leaving a small amount of ferruginous ash. It contained 5·87 per cent. of sulphur.

The chloroform soluble is not a constant constituent of asphaltum. Many asphaltums have not a trace of it; others have only a trace, while in others still, the percentage is very small. In those asphaltums in which the chloroform soluble is wanting, the percentage of turpentine soluble is often very small. There are no physical properties that serve to distinguish these asphaltums to the eye. The asphaltum that contains only a trace of chloroform soluble and but a small percentage of turpentine soluble may be in appearance a brilliant black, brittle solid, not to be distinguished by the eye from one that consists of from one-third to one-half of chloroform soluble. The relation of physical to chemical properties has not yet been determined.

It may be that the chloroform soluble represents, in some instances, that portion of the asphaltum that has been in some manner deprived of its hydrogen. This condition is not necessarily brought about by weathering, although it cannot be denied that weathered asphaltums almost invariably yield a comparatively large percentage of chloroform soluble. The following analysis of materials from the deposit at Trinidad furnishes a remarkable example of this fact. In the following table, No. 1 represents the average composition of the ten specimens of crude commercial lake and land pitch, analyzed by Miss Laura A. Linton. No. 2 is the average composition of two specimens of alteration products of Trinidad pitch, one of which came from the lake, and the other from outside of it. I have also similar material from the weathered portions of asphalt veins in California.

	No. 1. Per Cent.	No. 2. Per Cent.
Petroleum ether soluble	34·612	20·306
Turpentine soluble	12·375	17·843
Chloroform soluble	5·757	13·968
Total bitumen	52·744	38·981
Organic material not bitumen	11·098	9·706
Mineral matter	36·160	38·175
Total bitumen soluble in petroleum ether	65·660	38·981
" " " " turpentine	23·391	34·195
" " " " chloroform	10·925	26·824

The material of which the analysis is given in column No. 2 may be what Mr. Richardson has called "chocolate pitch." It is a light brown, pulverulent solid, in form somewhat columnar, like starch, and just as easily rubbed into a powder between the fingers. It contains nearly three times the percentage of chloroform soluble that occurs in the average commercial pitch. Somewhere between the chloroform soluble of 10·925 per cent., which is found in the average commercial pitch, and the 26·824 per cent. found in this alteration product, the Trinidad pitch loses its tenacity and becomes friable. Of course, as the chloroform soluble is increased, it must be at the expense of the other ingredients. The petroleum ether soluble in this case is only about one-half the proportion given in column No. 1, the ratio being 38·981 : 65·66. The ratio of the chloroform soluble to the total bitumen is, in No. 1, 1 : 9·163, and No. 2, 1 : 2·789. The investigation of these problems has only just been entered upon, but it is a research of vast importance, and must in time command attention.

When these figures were first developed, from the results of Miss Linton's analytical work, it was hoped that some satisfactory explanation of the peculiar properties of glance pitch might be deduced. The claim that glance pitch is geologically old pitch is found to be entirely erroneous. The following table shows the compositions of five pitches, all of which are supposed to be cretaceous or older :

Per cent. of petroleum ether soluble in total bitumen	No. 1, 25·4605 " 2, 35·0870 " 3, 38·0300 " 4, 49·9590 " 5, 51·0430 " 6, 8·5106

Nos. 2, 5 and 6 are very brilliant glance pitch; the others are equally hard, but not as brilliant. The chloroform soluble varies in these from less than 1 per cent. in No. 6 to 32·5 per cent. in No. 4. Just as brilliant and hard glance pitch as any of these, I know to be a melted tertiary asphaltum, of which more than 75 per cent. is soluble in petroleum ether. Such discordant results, obtained from such a large number of asphaltums from widely different localities, have confirmed the opinion that the peculiar properties of glance pitch do not depend upon chemical composition, but are the result of the melting of the asphaltum.

Reviewing the results hereinbefore stated, a number of general conclusions may be drawn that are of interest in connection with the significance and value of technical analyses of solid bitumens and bituminous rocks.

In the reply that Captain Torrey makes to De Smedt, he refers to the sulphur content of asphaltum, and cites an article by O. Hesse (*Arch. d. Pharm.*). This reference has been made quite widely for some years. In attempting to verify it, I found that Oswald Hesse had been a frequent contributor to German scientific literature for about thirty years, but I cannot discover that he has ever published a word upon asphaltum. The article referred to is by Otto Helm, and is to be found in *Arch. d. Pharm.*, III, **13**, 396. Helm does not mention retine, petrolene or asphaltene; but he discusses the sulphur content of crude asphaltum. He does not definitely locate any of his specimens, and for this reason his work loses much of its value.

In the April number of *Paving* for 1894, De Smedt replied to the criticism of Captain Torrey. He makes some very sweeping statements, but he gives no authority for them. He does not give any references, nor are we informed whether his statements are based upon his own researches

or those of others. I have made a very careful search in the scientific periodical literature of the last thirty years and I can find nothing by others, nor does my own experience confirm the statements made in this article. I have never seen any positive evidence that free sulphur exists in Trinidad pitch. It is possible that it does. I am of the opinion that the cases are extremely rare where free sulphur is mixed with any bitumen.

De Smedt asserts that petrolene contains of sulphur 9·20 per cent., and that asphaltene contains of sulphur 12·89 per cent. Miss Linton's analysis shows grahamite to consist of practically 50 per cent. each of petrolene and asphaltene. This would give, according to De Smedt, 11·045 per cent. of sulphur in grahamite. A careful determination of the sulphur in the specimen of grahamite used by Miss Linton shows it to contain 0·6125 per cent. of that element. It also contained a small percentage of iron, which I did not determine. It is probable that this iron and sulphur are combined as pyrites, together forming about 1 per cent. of the mineral. Less than 1 per cent. of albertite is soluble in petroleum ether. The mineral is practically all asphaltene. According to De Smedt, it ought to contain 12·5 per cent. of sulphur. A very careful determination of the sulphur in albertite gave 0·2023 per cent., and not a trace of iron.

If De Smedt's figures were correct, a bitumen containing 90 per cent. of petrolene should contain 8·28 per cent. of sulphur, whereas such an one actually contained 1·5 per cent. Another, consisting of 70 per cent. petrolene and 30 per cent. asphaltene, should contain 10·3 per cent. of sulphur; such an one actually contained 7·5 per cent. I have never seen a bitumen that contained 10 per cent. of sulphur. These examples show that whatever may have been the basis from which De Smedt drew his conclusions, he was entirely mistaken according to the facts.

These names have figured in another role. In the testimony given in the trial of the well-known Peoria suit, it was asserted by several witnesses that petrolene was the cementitious portion of asphaltum, and also that residuum

oil was without cohesion, and that asphaltene was as inert as so much sand. They practically defined petrolene as that portion of an asphaltum that is soluble in petroleum ether. I have made many analyses, by solution, of street surfaces, some of which were well known to be very good, and some very bad. If the claim of these witnesses is correct, no one will dispute that the petroleum ether soluble—denominated petrolene in these cases—included whatever residuum oil might have been added to the Trinidad pitch to soften it, and would therefore lessen, by whatever its proportion might be, the cohesion (and also adhesion) of the original petrolene, for the other constituents of the mixture, including the inert asphaltene and sand. The amount of this petroleum ether soluble is surprisingly small. It rarely amounts to an average of more than 6 per cent., and is often less.

I do not question the intentional veracity of any of these witnesses. They were making assertions which they believed, and very much desired, should represent the truth, but in my judgment they were greatly mistaken. If street surfaces constructed of the "best pitch lake asphalt" are held together by *only* 5 per cent. or a little more of cementitious matter, it is not remarkable that they go to pieces in a few months, but that they hold together at all. The fact is that the cementitious principle of a street surface consists in the total amount and character of the bitumen that the surface mixture contains.

The danger of basing any general conclusions upon such reasoning as was employed by these witnesses can only be fully appreciated when it is recognized as a fact that the portions of different bitumens dissolved by petroleum ether have no necessary chemical identity, or even close resemblance, to each other; that they vary greatly in amount, in consistency, in tenacity, and many other physical properties. These facts being recognized as established beyond dispute, the question arises, of what value is a technical analysis of asphaltum by solution? The value lies *only* in analyses made with the same solvents under the same conditions, as a means of comparison, especially when applied to

different specimens from the same locality. The analyses should not only be made with the same solvent and in precisely the same manner, but the results should be reported in precisely the same manner, in order that direct comparisons may be made of them. It is the height of folly to attempt to compare things that are different or that are stated differently. When, therefore, Pacific Coast asphaltums are dissolved in a Pacific Coast petroleum ether, or in acetone, and anything is affirmed concerning them, as compared with Trinidad or Bermudez asphaltum that have been dissolved in ethyl ether or petroleum ether from Eastern petroleum, the analyst is wholly unfair and in the end defeats the purpose of analysis. Giving these unlike products the same arbitrary name only increases the confusion.

For these reasons we insist that a uniform method by the same solvents should be adopted by all those who are engaged in analyzing asphaltum.

In the article published in the March number of *Paving* for 1894, Captain Torrey says, in reference to the use of the names retine, petrolene and asphaltene: "With the present knowledge of them, it would be better not to use these misleading names, but others more appropriate." In this opinion I fully agree, and would add that for some time past I have sought to discard them, and to report the percentage soluble in petroleum ether and other solvents as "the petroleum ether soluble," and not as petrolene, etc.

NOTES CONCERNING RETENE, ETC.

[1] *Paving and Municipal Engineering*, Nov., 1893, p. 206.

[2] *Paving and Municipal Engineering*, *vide*, 1894.

[3] *Journal of the Franklin Institute*, **149**, 29.

[4] *See* Clifford Richardson, *Journal Soc. of Chem. Ind.*, **17**, 14.

ELEMENTARY GRAPHICS AND GEOMETRY OF THERMODYNAMICS.

BY ROBERT H. THURSTON.

Diagrams of Energy represent the method of variation of energy and of work in any system in which such variation occurs as a function of quantities of which the varying magnitudes may be represented graphically. These magnitudes are exhibited on such diagrams by the coördinates of points representing the condition of the substances, and their variations, by lines which are the loci of successive positions of those points.

Thermodynamic Diagrams exhibit the varying thermal states of a working substance, and the mechanical effect of thermal changes when heat-energy and mechanical energy are converted, the one into the other. In such diagrams, the coördinates usually, but not necessarily, measure pressures and volumes of the working fluid.

Thermal Lines are such as, in thermodynamic diagrams, exhibit the change of condition of the working substance. They are generally, in all applications of practical nature, lines of which the ordinates measure pressures and the abscissas measure volumes.

Isothermal Lines, or lines of equal temperature, are such as represent, on a diagram of energy, variations of pressure and volume occurring while the temperature of the substance remains unchanged. They have the equation $p\,v =$ constant when the working substance is a perfect gas.

Adiabatic Lines, or *Isentropic Lines*, are lines exhibiting variations of pressure and volume when the substance is caused to change its condition within a non-conducting vessel or chamber, no heat being permitted to enter or to leave it. They are " lines of no transmission of heat," and have the equation, for gases, $p\,v^{\gamma} =$ constant, in which v^{γ} is the ratio of the specific heat at constant pressure to that at constant volume. In all such operations, the " thermodyna-

mic function," and variation of entropy, the variation of heat per unit of temperature, are constant.

Isodiabatic Lines are sets of lines, two or more, along which equal quantities of heat are transferred to and from the working substance.

Isodynamic Lines are those which represent variations of volume, and of pressure, during which the total internal energy is retained constant, heat being supplied or rejected to compensate any loss by the expenditure of internal energy in doing external work or in wastes of heat. In other words, the sum of the actual energy of sensible heat and the potential energy due molecular relations of position is constant during any isodynamic change.

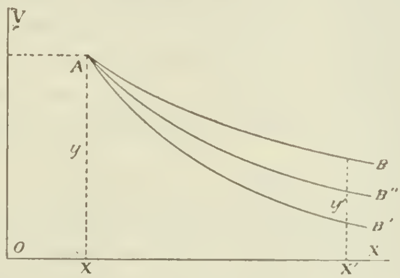

FIG. 1.—Thermal lines.

The Relation of the Thermal Lines is seen in the accompanying diagram of energy, *Fig. 1.*

Let $A\ B$ be the isothermal line of a substance expanding from the pressure and volume $A\ x$, $O\ x$, to the pressure and volume $B\ x'$, $O\ x'$. An adiabatic line will fall below $A\ B$, as at $A\ B'$; since the temperature of the fluid is held constant, during isothermal expansion, $A\ B$, by supplying the quantity demanded for conversion into external and internal work, or mechanical energy; while, during adiabatic expansion, no heat is so transferred to the fluid, and its temperature, and therefore its pressure, must, in the latter case, fall. In the one case, all heat transformed into work is supplied from without; in the other case, such work must be done at the expense of the store of heat originally contained in the mass.

The adiabatics and isothermals approach each other the more closely as the temperature is reduced, and as less work is done in expansion, until, at absolute zero, all heat motion ceasing, they coincide with their common asymptotes, and coördinate axes.

The isodynamic line, $A\ B''$, falls between the isothermal and the adiabatic; since the heat demanded for the performance of interior work is, or may be, furnished by drawing upon the initial stock of sensible heat, while only enough must be supplied from without to do external work. With perfect gases, the isothermal and isodynamic lines are evidently coincident, since no internal work can be done in their expansion.

It is evident that all these thermal curves, being lines of which the abscissas represent volumes and the ordinates coincident pressures, they all have common asymptotes in the coördinate axes and the "curve of absolute cold,"* which is a curve at once of isothermal, isodynamic, and isentropic expansion.

The Thermodynamic State of a substance is its condition as related to its temperature, pressure and volume. In perfect gases these properties are so related that, for unity of weight, the quotient of the product of the pressure, p, and the volume, v, by the absolute temperature, T, is constant, *i.e*,

$$\frac{p\ v}{T} = \text{constant.}$$

It thus follows that the state of the body is determined whenever either two of these three variable quantities is known. For isothermal expansion, $p\ v = \text{constant}$;

$$p \propto \frac{1}{v};$$

in isometric expansion, in which v is constant,

$$\frac{p}{T} = \text{constant,}$$

and $p \propto T$; for isopiestic expansion, in which p is constant,

*So named by Rankine.

$$\frac{v}{T} = \text{constant},$$

and $v \propto T$. For adiabatic expansion, in which the total heat is invariable, except by transformation, $p\,v^\gamma$ constant, and

$$p \propto \frac{1}{v^\gamma}.$$

Proposition 1.—The thermodynamic state of any gaseous substance, and its variations, may be indicated by the positions of points on a diagram of energy, of which points the coördinates are measurable in terms of pressure and volume.

For, let the thermodynamic state of the given substance be such that its heat-energy is known and can be measured in units of work, and let its specific volume* and its pressure be known; its temperature and its physical condition are then fully known. Since, in such cases, the state of the substance is known when either two of the three variables, pressure, specific volume, and temperature, are known, it is fully defined by pressure and volume, and these quantities being measured by the coördinates of a point on a diagram of energy, the position of that point represents and defines the thermodynamic state of the substance.

The variation of the position of the point so defining the condition of a substance evidently exhibits the variation of such condition.

Corollary 1.—When the substance has a pressure and a volume due solely to the action of thermal energy, *e. g.*, a perfect gas, the coördinates of the point representing its physical state may be taken on a diagram of energy as measures of its actual pressure and volume; otherwise such coördinates in diagrams of energy may measure either the external pressure confining the fluid, or the internal forces, as of molecular attractions or repulsions, or the sum of external and internal forces, accordingly as it is proposed to measure variations of external, of internal, or of total work, during changes of condition.

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*Specific volume is the volume of unity of weight.

Corollary 2.—A fluid possessing a fixed quantity of total energy, represented by a function of pressure, volume and temperature, may be represented by an indefinite number of points, each defining a relation of pressure and volume determined by the temperature of the substance in the assumed condition. Such points must all fall into a line, which may be called that of equal energy, a line which has already been denominated the isodynamic line.

Scholium 1.—A gaseous fluid of which the volume and pressure are defined solely by the quantity of heat-energy with which it is charged, and in which, consequently, the temperature is constant for equal energy, will, in such case, have a constant value for the product of pressure and volume; its isodynamic line has the equation $p\,v =$ constant. The isodynamic line of a perfect gas is, therefore, an equilateral hyperbola.*

Corollary 3.—The quantity of heat contained in the unit of weight of a perfect gas being measured by the product of its absolute temperature into its specific heat, when the temperature is constant, $p\,v =$ constant $= R\,T$ and the isothermal expansion line of a perfect gas is an equilateral hyperbola.

This is the law of Boyle and Marriotte.

Scholium 2.—The isothermal and isodynamic lines of the perfect gas are identical.†

Corollary 4.—The adiabatic, or isentropic, line of any fluid, as presented in a diagram of energy, falls below the isothermal line to an extent which measures the transformation of heat in doing the work of expansion; in its equation, $p\,v^\gamma =$ constant, therefore, γ, whether constant or variable, exceeds unity for the perfect gas and for all other fluids is greater than the value for isothermal expansion. If hyperbolic, these curves are, therefore, of a higher order of hyperbola than the equilateral.

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*This is approximately true for permanent gases, and for vapors far removed from their temperatures of liquefaction.

†They are nearly identical for permanent gases, and for vapors far removed from their points of liquefaction.

Proposition 2.—The total quantity of heat transformed by the expenditure of energy in the work of expansion of any fluid, against internal or external forces or both, and in thus doing internal or external work or both, is measured on a diagram of energy by the area included under the curve representing the changes of pressure and volume occurring while such expansion is in progress.

For, since in any such diagram the ordinates measure resistances and the abscissas are proportional to the spaces through which such resistances are exerted, the work done will be measured by summing the products of resistances into space, or integrating the differential areas between the limits of such expansion, and thus obtaining a measure of the area under the expansion line.

But, according to the first law of thermodynamics, the work so done is the equivalent of the quantity of heat transformed into mechanical effect during the operation. Hence, the area so measured is a measure of the total heat so transformed and of the total work so done.

Corollary 1.—When the work represented on the diagram is that done against external forces, the heat thus measured is the total amount transformed into external work; when the ordinates measure internal resistances, the heat measured is that transformed in doing internal work; when the ordinates measure total resistances, external and internal, the work and heat measured are the total work done and the total heat transformed in performing it.

Scholium 1.—The diagram of energy of a perfect gas always measures total work done, all such work being, in such a case, external; and the ordinates are proportional to the tension of the gas. The diagram for any other fluid may be of either class.

Scholium 2.—The specific heat of constant pressure is measured by the sum of the heat demanded to produce a change of temperature, unity, in a stated volume, and that required for transformation into total work, external and internal, as exhibited on diagrams of energy. The specific heat of constant volume is simply that demanded to produce change of temperature and is not dependent upon the nature

or method of variation of internal work ; it is the *real* specific heat of the substance.

Proposition 3.—The total thermal and intrinsic energy which may be drawn upon in the performance of work by the expansion of a fluid is measured, on a diagram of energy, by the area included under the adiabatic curve, extended indefinitely in the direction of increasing volume from the point representing the initial state of the substance.

For, in the figure let $A\ B$ be the adiabatic, or curve of no transmission of heat, for a substance expanding from the initial state A, until, all its stock of heat-energy being expended, its temperature and its tension become zero, and its volume indefinitely large.

The work done, as measured on the diagram, according to the definition of the adiabatic line and the first law of thermodynamics, is performed at the expense of the initial stock of energy, but this work is the exact equivalent of the heat transformed, and is exactly measured by the area of the diagram of energy, $A\ B \ldots . X\ x_1\ A$, included between the curve and the ordinate y_1 and the base $O\ X$.

Hence, this area measures the heat originally available in the state A, for transformation into mechanical energy or work.

Corollary 1.—When the ordinates of the adiabatic curve measure the external pressure, as always with perfect gases, and usually with other fluids, the diagram represents the external work performed ; when representing internal resistance to expansion, due to cohesion, or molecular attractions, the work measured is similarly wholly internal ; when measuring the sum of the two resistances, the diagram represents total internal and external work obtainable by total transformation of heat.

Proposition 4.—The energy transformed from the thermal to the mechanical condition during any limited, adiabatic, change of state is measured, on a diagram of energy, by the area included under the adiabatic line passing through the two points representing the initial and final states of the substance, and between the ordinates of those points. This quantity thus measures the total loss of heat by the expanding fluid.

For, in the figure, the areas $A\ A'\ B \ldots\ldots X\ x_1\ A$, and $A'\ B \ldots\ X\ x_2\ A'$, measure, respectively, the energy available in the two states, $A\ A'$; the difference can only have been expended in the production of work measured by the difference of those areas, $A\ A'\ x_2\ x_1\ A$, which, therefore, is a measure of the heat so transferred and transformed, and thus lost or gained by the substance by expansion or compression.

Proposition 5.—The quantity of sensible heat gained or lost by a fluid in passing from one state to another without change of volume is represented on a diagram of energy by the area included between two adiabatic or isentropic lines of indefinite extent, and the ordinate common to the two points representing the initial and terminal states.

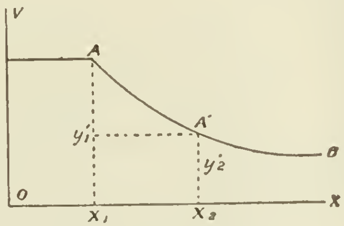

FIG. 2.—Stored heat.

For, in *Fig. 3*, the thermal energy of the body, or its sensible heat, in either of the two states, as A or A', is measured by the area of the diagram under the adiabatic, indefinitely prolonged toward X, as $A\ B \ldots X\ x\ A$, and $A'\ B' \ldots X\ x^1\ A'$; and the difference of those areas, $A\ B \ldots X \ldots B'\ A'\ A$, must, therefore, measure the difference of thermal energy and the heat gained or lost in passing from the one state to the other.

Scholium 1.—The total amount of heat received or surrendered by any substance, in passing from one state to another, is the sum of the quantities demanded for transformation into work, as shown on the diagram of variation of total work or energy, other than thermal, and that required to produce thermometric changes and consequent changes of pressure. The total amount of heat gained or lost, received

or rejected, during any change, is thus determined by the method of expansion or compression of the fluid.

Scholium 2.—The quantity of heat lost or gained during such changes as occur isometrically cannot be measured on a diagram of energy which simply exhibits that change.

Scholium 3.—No change, by transformation of heat into mechanical energy, or productive of mechanical work, can occur isometrically, but must be produced by changes of volume.

Proposition 6.—The quantity of heat absorbed, and the quantity transformed into work or energy, during isothermal change, is measured, on a diagram of energy, by the area included under the isothermal expansion line and between the

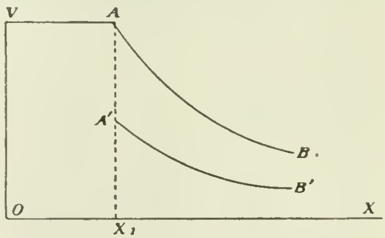

FIG. 3.—Isometric change.

ordinates of the two points representing the initial and terminal states of the body; the diagram measuring the total work done, both exterior and interior; its ordinates being taken to measure total pressure.

For, in *Fig. 2*,* assuming $A\ B$ to represent an isothermal line traversing A and A', the ordinates of the curve measuring the sum of external pressure and internal attraction, should the fluid not be a perfect gas, the total work done during the change is measured by the area $A\ A'\ x_2\ x_1$. This is also the equivalent of the heat transformed into work. But, the temperature remaining constant, no other change demanding accession of heat occurs, and the quantity so measured is a measure of the heat absorbed by the substance during such an isothermal change.

* Figure in Proposition 3.

Scholium.—The area included between a pair of adiabatic lines, similarly drawn from a common initial to a common terminal ordinate, measures the difference in the amount of external work which may be done by transformation of heat, in consequence of the isometric change of condition between the initial points on the two lines; internal work being obviously the same in both cases.

Proposition 7.—When change of volume occurs at constant pressure—*i. e.*, during isopiestic changes—the total amount of heat absorbed or emitted by the working substance is equal to the sum of the amounts demanded to produce change of temperature and for transformation into work; the increment of heat demanded for each of the two changes is constant, and the flow of heat is directly proportional to

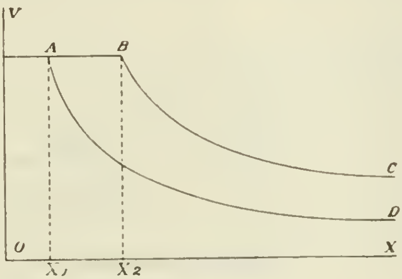

FIG. 4.—Isopiestic change.

the variation of area of the diagram representing the change, and to the variation of volume.

For, let the alteration of volume occur between A and B, and at the constant pressure $A\ x_1$. Let $A\ D$, $B\ C$, be a pair of adiabatics, drawn from A and B indefinitely toward X. Then, during such an isopiestic change, the variation of energy will be measured by the area $A\ D \ldots . X \ldots C\ B\ A$, while the work done under the pressure $x_1\ A$ will be measured by the area $A\ B\ x_2\ x_1\ A$; and the total variation of heat by absorption during expansion, or by emission during compression, will be measured by these two quantities.

Since the areas are similar and are proportional to their measures on the axis of abscissas, their altitude remaining constant, the influx or efflux of heat, being proportional

to the energy so represented, must occur at a rate directly proportional to the rate of change of volume of the working substance and of these areas.

Corollary.—The coëfficient for specific heat at constant pressure is thus constant for elastic fluids.*

Proposition 8.—The total quantity of heat absorbed or emitted by any fluid, in passing from any one condition, such as may be represented on a diagram of energy, to another, is measured by the area included between the line representing the change and a pair of adiabatic or isentropic curves drawn from its extremities, indefinitely, in the

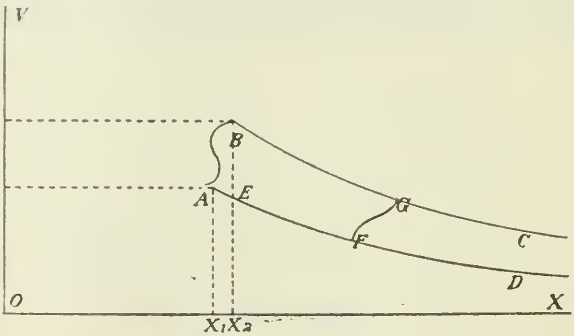

FIG. 5.—Rankine's principle.

direction of increasing volume, and until they become asymptotic with the axis of volumes.

For, in *Fig. 5*, let this change take place between A and B. Then the work done may be represented by $A\ B\ x_2\ x_1$, and the variation of thermal energy by $A\ B\ C \ldots X\ D\ A$; since $E_1 = A\ D \ldots X\ x_1\ A$, is the energy of the mass at A, and $E_2 = B\ C\ X\ x_2\ B$ is that at B; while $E_3 = A\ B\ x_2\ x_1\ A$, is the work done in the change, and $E_4 = E_2 + E_3 - E_1 = A\ B\ C \ldots \ldots X \ldots D\ A$, is the measure of the net variation of heat-energy, which amount must be supplied during expansion or withdrawn during compression.

*This was shown by Carnot (1824), by deduction from thermodynamic principles, and experimentally, by Regnault.

Or, let the mass expand along $B\ C$ until its stored energy is expended in work; then compress the fluid until it passes adiabatically to A, and thence back to B, the transfer from the adiabatic $B\ C$ to the adiabatic $C\ A$ being thus effected without measurable variation of heat-energy. The net work performed during this operation is measured by the area between the two adiabatics and the original path $A\ B$, and this area is therefore the measure of the total heat demanded or rejected.* More explicitly, the work done during expansion from A to B is measured by the area $A\ B\ x_2\ x_1\ A$; that equivalent to the stored energy at B is measured by $B\ C \ldots X \ldots x_2\ B$; while that originally stored at A is measured by $A\ D \ldots X\ x_1\ A$. The net amount, measuring the total of all heat demanded during the operation, is therefore $A\ B\ C \ldots X \ldots D\ A\ B$ as before.

Scholium 1.—If the line $A\ B$ is isothermal, in order that temperature may be preserved constant, heat must evidently be supplied during expansion, or rejected during compression, in amount equal to the total work done, and the area between the two adiabatic expansion lines measures the latent heat of expansion at constant temperature. When $A\ B$ is a line of constant pressure the area measured is proportional to the work equivalent to the total heat of expansion under constant pressure.

Scholium 2.—Since the thermal state of a body depends on its actual physical condition, and not upon the method of attaining that condition, the difference between the total heat absorbed or emitted and the work done in any change is dependent solely upon its initial and final states, and is entirely independent of the method of change, *i. e.*, of the form of the curve or path $A\ B$.

Scholium 3.—The quantity of work done during any change, as $A\ B$, is variable with the method of producing the change, as represented by the curve; whence the total heat demanded or emitted during such change is dependent upon the method of variation. An infinite number of paths may be taken between A and B, no two of which will pro-

*This is substantially the demonstration of Rankine; "Steam Engine," p. 303.

duce the same total variation of heat-energy in the system, while the difference of intrinsic or stored energy may be the same for all.

Scholium 4.—Since the internal work during any change, $A B$, is precisely the same for a definite change of volume, however produced, the internal work done along the line $A B C \dots X$ is equal to that done along the line $A D \dots X$, and the difference of area $A B C \dots X \dots D A$ is independent of internal work, and the proposition applies equally to perfect gases and to other fluids.

Corollary 1.—Two points being taken in each of two adiabatic lines, as A and F, B and G, the difference in the quantity of heat absorbed or emitted in transfers by the two routes $A B$, $F G$, from adiabatic to adiabatic, is measured

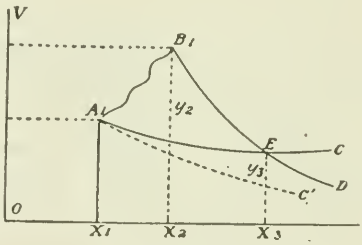

FIG. 6.—Heat absorption.

by the area $A B G F$, included between the two adiabatics and the two lines indicating the two routes and marking the method of change; this area measures work done, equivalent in amount to the difference in quantity of heat so transferred and transformed into work, and that retransformed into heat.

Corollary 2.—The two routes of transfer being isothermal, the difference in quantity of heat absorbed or emitted is measured by the area included between the two isothermals and the two adiabatic lines.

Corollary 3.—Transfer from adiabatic to adiabatic being effected along lines of constant pressure or lines of constant volume, the areas included between the pair of adiabatics and the pair of isopiestic or of isometric lines measure the difference in quantity of heat transferred.

Proposition 9.—The total quantity of heat absorbed or emitted by a substance, in passing from one condition to another, such as may be represented on a diagram of energy, is measured by the area included under the line representing such change and an adiabatic curve drawn from the upper extremity of that line to the point of intersection of the adiabatic with the isodynamic line, from the other extremity of the curve representing the change. *Fig. 6.*

Let *A B* be the line of transfer from the state *A* to the state *B*. Draw from *A* the isodynamic line *A C*, meeting the adiabatic from *B* at *E*. The curve *B D* then represents the method of variation of pressure and volume when no heat is absorbed by, or emitted from, the fluid, during change of volume; while the curve *A C* represents the variations of pressure and volume when its internal energy does not change.

Then will the total variation of heat, by absorption or emission, during the change *A B* be measured by the area, $A\ B\ E\ x_3\ x_1\ A$, included between the lines *A B*, *B E*, and the ordinates to *A* and *B*.

For, (1)—The lines *B D*, *A C*, must intersect; since heat is supplied along the line *A C*, to preserve the original stock of internal energy while work is done by expansion; and during expansion along *B D*, no heat is added, and pressure must therefore diminish more rapidly along *B D* than along *A C*, and, at some point, *E*, they thus intersect, the pressure and volume becoming the same for both lines, and the internal energy at *E* being equal to that at *A*.

(2) The total heat furnished along *A B* is the sum of that demanded to perform work and that required to produce variation of internal energy; the first is measured by the area $A\ B\ x_2\ x_1\ A$; the second is measured by the area $B\ E\ x_3\ x_2\ B$, since the work so measured is performed by the surplus of heat supplied along *A B* over that demanded to do the work of expansion; at *E* all internal energy so gained between *A* and *B* has been transformed into work. Hence the heat absorbed during the change *A B*, or emitted during the change *B A*, is measured by the equivalent work under the lines *A B* and *B E*.* Q. E. D.

*This use of the isodynamic line is due to Cazin.

Scholium 1.—The area under $A\ B$, $B\ E$, as above, is equal to that included between two isentropic lines $A\ C'$, $B\ D$, extending from A and B, indefinitely, in the direction of increasing volume.

Scholium 2.—When the line $A\ B$ is isothermal, the area measured as above is proportional to the latent heat of expansion at constant temperature.

Scholium 3.—If the line $A\ B$ is a line of constant pressure, the heat so determined measures the total heat of expansion at constant pressure.

Scholium 4.—If $A\ B$ is a line of constant volume, the total heat of expansion at constant volume is obtained.

Scholium 5.—If $A\ B$ is adiabatic, no heat is absorbed or emitted, the measured area becoming zero, and if $A\ B$ is isodynamic, all heat absorbed or emitted is that transformed from or into work; the total area measured is proportional to that work.

Corollary 1.—The area $B\ E\ x_3\ x_2\ B$ measure the equivalent of so much of the heat gained or lost by the body, during the change $A\ B$, as escapes transformation into work.

Proposition 10.—The internal energy gained or lost by a body, by a process of change represented, on a diagram of energy, by any line, as $A\ B$, is measured by the area included between an isentropic (adiabatic) line passing through the higher terminal, B, of that line, and the base-line, and limited by ordinates passing through that point, and through the intersection of that isentropic line with the isodynamic curve drawn through the other terminal of the path of transfer.

Let $A\ B$, *Fig. 6*, represent the route by which the substance is transferred from the state A to the state B, or the reverse. Then will the area, $B\ E\ x_3\ x_2\ B$, included between the isentropic line $B\ E$, and the base, $x_2\ x_3$, measure the internal energy gained or lost between A and B.

For, the total heat absorbed is measured by $A\ B\ E\ x_3\ x_1\ A$, of which the quantity $A\ B\ x_2\ x_1\ A$, only, is expended in external work; the remainder, $B\ E\ x_3\ x_2\ B$, must therefore measure the heat transferred in producing the variation of internal energy.

Scholium.—If the body is gaseous, the isodynamic line is also isothermal, and the area above measured is then proportional to the heat transferred without conversion, producing variation of temperature, *i. e.*, kinetic energy of molecules; and this area measures also the latent heat of expansion.

[*To be concluded.*]

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, December 19, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 19, 1900.

President JOHN BIRKINBINE in the chair.

Present, 58 members and visitors.

Additions to membership since last report, 48.

The Actuary reported from the meeting of the Board of Managers held Wednesday, December 12th, a preamble and series of resolutions making formal protest against the adoption, by the Trustees of the Franklin Fund of the city of Boston, of the name of the Franklin Institute to designate an institution of the applied sciences, which it is designed to found in Boston with the proceeds of this fund.

The President gave some explanations respecting the origin of this fund, and of a similar fund in Philadelphia, and stated that correspondence had been opened by the Secretary, under the instructions of the Board, with his Honor, the Mayor of the city of Boston, with the view of making the protest effective.

Mr. Louis E. Levy, delegate of the Institute to the Paris Exposition, presented his report, which covered substantially an account of the proceedings of the Congress of Associations of Inventors.

Mr. Joseph L. Ferrell, of Philadelphia, gave an account of the development of the art of fireproofing wood, with especial reference to the method and apparatus of the United States Fireproof Wood Company.

On Mr. Levy's motion, the subject was referred to the Committee on Science and the Arts.

The paper of Mr. Ferrell was discussed by Dr. S. P. Sadtler, Dr. Wahl, Mr. Joseph Richards and Mr. Wm. McDevitt.

The following nominations were then made in conformity with the bylaws:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	GEO. V. CRESSON.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" one year)	SAMUEL SARTAIN.
" *Auditor*	(" three years)	JNO. GEORGE COPE.

For Managers (to serve three years).

DANIEL BAUGH,
ROBT. C. H. BROCK,
STEPHEN GREENE,
HENRY HOWSON,
ALFRED C. HARRISON,
HENRY R. HEYL,
ALEX. KRUMBHAAR,
C. HARTMAN KUHN.

In place of SAMUEL F. HOUSTON (resigned),
BENJAMIN SMITH LYMAN.

For Members of the Committee on Science and the Arts (to serve three years).

L. L. CHENEY,
JAMES CHRISTIE,
G. H. CLAMER,
J. M. EMANUEL,
J. LOGAN FITTS,
FRANCIS HEAD,
CHAS. A. HEXAMER,
J. Y. MCCONNELL,
WM. MCDEVITT,
L. F. RONDINELLA,
ARTHUR J. ROWLAND,
SAMUEL SARTAIN,
T. CARPENTER SMITH,
THOMAS SPENCER,
JOHN C. TRAUTWINE, JR.

The President named the following members to serve as tellers of the annual election, to be held on Wednesday, January 16, 1901, between the hours of 4 to 8 o'clock P.M., viz.: Jas. H. Carpenter, Richard Gilpin, Wm. O. Griggs, F. M. Sawyer, Harrison Souder, C. Walton Swoope, Warner Walter.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, December 5, 1900.*]

MR. H. R. HEYL in the chair.

The following report was adopted:

(No. 2122.) *Reconstructed Granite as an Insulating Material for Electrical Uses.*—The Reconstructed Granite Company, New York. (Referred to the Committee by the Bureau of Awards of the National Export Exposition.)

ABSTRACT.—Reconstructed Granite is a manufactured product made substantially as follows.: Chips of natural granite are calcined by being subjected to a high temperature and afterwards pulverized. The material is then thoroughly mixed with ground feldspar and kaolin, enough water is added to make the mixture plastic, and it is then moulded into the desired forms under heavy pressure. After being dried it is subjected to a temperature sufficient to cause the incipient fusion of the silicates present. When in-

tended to be used for electrical purposes the surface is given a vitrified glazing which increases its insulating qualities by rendering the mass much less porous, and consequently more impervious to moisture.

It is claimed for this product, in respect of its adaptability for electrical uses, that it is absolutely fire-proof; that it resists the action of all solvents and acids except hydrofluoric acid (which attacks it superficially); that it is frost-proof; that it is impervious to moisture. and that it has high insulating qualities.

A series of tests made by the investigators to determine the validity of these claims established the fact that the material is substantially fire-proof, acid-proof and water-proof. No test of its frost-proof qualities was made

The average of several results gave the material a crushing strength of about 10,000 pounds per square inch, and a tensile strength of about 950 pounds per square inch.

Careful tests of the electrical insulating qualities of this product confirmed the claims of the manufacturers. As the result of their tests, the investigators report that "the ohmic resistance of the samples is very high."

Reference is also made in the report to the successful employment of this product for third-rail insulation, and for various applications in railway equipment.

From the tests made by the committee's investigators, and the testimony submitted, the conclusion is announced that reconstructed granite possesses distinct advantages for many forms of application as a material for electrical insulation. The award of the John Scott Legacy Premium and Medal is recommended to the inventors, Thos. Wilkinson Blakey, of Keene, N. H., and Wm. Courteney, of New York. [*Sub-Committee.*—Geo. A. Hoadley, Chairman; C. H. Bedell, Arthur J. Rowland, Wilbur M. Stine.]

The following passed first reading :

(No. 2107.) *Grate Bars.*—James Reagan, Philadelphia. (Referred by the Bureau of Awards of the National Export Exposition.) This report was referred back to the sub-committee, to investigate an alleged anticipation of Mr. Reagan's invention.

(No. 2124.) *The Facer Forged-Steel Car and Locomotive Wheel Company's Wheel.*—Philadelphia.

(Nos. 2145-2146.) *Method of Compressing Air by the Direct Action of Water. Raising Water by Means of Compressed Air.*—Jos. P. Frizell, Boston, Mass.

(No. 2154.) *Improvement in Light-Projecting Glasses.*—American Prismatic Light Company, Philadelphia.

(No. 2159.) *Surface-Grinding Machine.*—Gustav R. Landman, Philadelphia.

(This report was made advisory.) W. H. W.

SECTIONS.

(*Abstracts of Proceedings.*)

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, December 6th. Dr. Henry Leffmann in the chair.

Mr. Theo. D. Rand presented a communication on the "Microscopic Structure of the Rocks of the Philadelphia Section," which was freely illustrated with the aid of thin sections, projected on the screen with the lantern-microscope.

F. M. SAWYER,
Secretary.

ELECTRICAL AND CHEMICAL SECTIONS.—*Joint Meeting*, held Thursday December 20th. Mr. Joseph Richards in the chair.

Mr. Chas. J. Reed read the paper of the evening on "Electro-Chemical Action," which was illustrated freely with the lantern, the blackboard, and experiments. Discussed by Dr. Joseph W. Richards, Mr. Carl Hering, the author and others. Referred for publication in full. The presiding officer expressed the thanks of the meeting to the author.

RICHARD BINDER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, December 12, 1900. Mr. Joseph Richards in the chair.

After the transaction of formal business, Mr. Charles Morris, of Philadelphia, read a communication on "Subterranean Waters." Discussed by Prof. F. L. Garrison, Dr. Henry Leffmann, Mr. J. C. Trautwine, Jr., Mr. James Christie and the author. (The paper was referred to the Committee on Publications.)

The meeting passed a vote of thanks to the speaker for his interesting contribution.

Mr. Edwin S. Balch gave an account of a curious occurrence of a soft calcium carbonate in a small cave located near North Dorset, Vermont, which he had visited. This material was found lining the walls of the cave, and could cut away with a knife like so much cheese. When dry the substance became pulverulent. It was found on analysis to be calcium carbonate.

The same speaker exhibited a photograph of an interesting natural bridge of marble occurring in a marble quarry near North Adams, Mass.

Adjourned.

WM. H. WAHL,
Secretary pro tem.

JOURNAL

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FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLI, No. 2. 76TH YEAR. FEBRUARY, 1901

THE FRANKLIN INSTITUTE.

Stated Meeting, held December 20, 1899.

THE PHILADELPHIA CITY HALL CLOCK.

BY WARREN S. JOHNSON, M. AM. SOC. M. E.

For many centuries the pendulum has been recognized as the fundamental element in a mechanism for indicating and recording time. The characteristic of the pendulum which gives it its supreme place in clock mechanism is the fact that a pendulum of a given length, at the same point and elevation, will oscillate in equal periods. This is the theoretical statement of the fundamental law. In order that a given pendulum should follow this law, it must be relieved of two disturbing influences; namely, friction and external influences retarding or varying its original motion. The friction is from two sources: between the parts of the mechanism and between the pendulum and the surrounding air. This friction not only varies the oscillations of the pendulum from their normalcy, but ultimately brings the

pendulum to rest. Unaffected by the disturbing causes which I have mentioned, a pendulum would continue to move forever when once put in motion. The sole object of applying springs or weights to a clock mechanism is to supply the exact amount of energy lost in friction. As it is impossible to make a pendulum to operate under ideal conditions, springs or weights must be used; but to reach as near perfection as possible, the entire mechanism must be reduced to its simplest form. A simple pendulum has mechanical friction at only one point and that is the point of suspension. This is reduced to a minimum by avoiding a bearing in which one part rubs against another, using instead a very thin suspension spring, wherein the only friction is produced by the flexure of the spring as the pendulum oscillates. The air friction, not being avoidable, is made as uniform as possible by enclosing the pendulum in an air-tight casing. A simple pendulum, however, would not indicate or record time and hence it is necessary to add indicating devices called hands, which move in accordance with the oscillations of the pendulum. The whole mechanism, therefore, consists of a pendulum, an application of power to balance friction, and recording and indicating hands. The power mechanism acts upon the pendulum to keep it in motion, and the pendulum, through a detent, reacts upon the power mechanism, so as to use the energy in uniform and equally divided amounts at exact intervals, namely, at each swing of the pendulum. Even allowing for the disturbing elements of friction and the external interferences, the pendulum would still be theoretical, since I have considered a pendulum which is always of a given length. Unfortunately, under natural conditions, a pendulum made of a single material will change its length at each variation of temperature, and means are, therefore, employed to counteract this variation by offsetting the expansion of one material against that of another, so as to, as nearly as may be, keep the pendulum at a constant length. No combination of materials, however, will exactly suffice, and, therefore, there is always under ordinary conditions a third disturbing element, namely, temperature, and this has more

influence proportionately on the variations of the clock than friction, since the friction, both mechanical and of the air, is constant, while temperature is variable within great ranges.

From the requirements and the natural difficulties under which they operate, accurate clocks must be of the finest workmanship, designed upon the highest principles in the horological art and removed from all disturbing influences as far as is possible. So far as the mechanism is concerned, what is called an astronomical clock comes the nearest to meeting the requirements. An astronomical clock is the simplest of all clocks, employing no additional mechanisms for striking the hours, etc. It is unnecessary for my purpose to go into the details of their construction, it being sufficient to say that there are as few bearings as possible, all bearings are jewelled, the gearing is the most perfect, the pendulum hung with the thinest spring which will sustain its weight; the pendulum is compensated, so far as possible, for variations in temperature and is protected from air movements and, so far as is possible, from jarring from external sources.

What I have previously written is to note, briefly, the principles and necessary conditions under which an accurate timepiece must work. Clocks at first were of the ordinary size and for use within buildings. Finally equal use was found for public timepieces by which the poor as well as the rich might benefit; in other words, a public convenience. That they might be serviceable at great distances, they were necessarily elevated and for the same reason were provided with dials of great magnitude as compared with house clocks, and the mechanism and power applied were proportionately increased. Aside from the increase of friction, there was the increased vibration, owing to the elevation; the external variations of temperature, which not only varied the length of the pendulum, but affected all lubricants which are necessary in mechanism. I have said that an accurate clock must have as little external mechanism as possible added to it. A tower clock, since its hands are exposed to wind and weather, requires at all times considerable energy to operate them, but

owing to changes of wind, and with snow and sleet, *varying* power to operate them. It follows that a tower clock built upon the lines of an ordinary enclosed clock of practical dimensions cannot be extremely accurate, while, being for public use, it should be the most accurate of all clocks.

The tower of the City Hall in Philadelphia was designed for a tower clock, but, owing to the extreme height of the tower and the size of the dial face, presented problems not before encountered in the installation of a tower clock.

The total height of the tower is 547½ feet from the ground, and the centers of the dials, 362 feet above the pavement. The diameters of the dial openings are 25 feet, including the rim. The height is so great that the dials are often obscured by clouds, and during the erection of the clock the ironwork was frequently wet with deposited moisture, while the pedestrians below were in a dry atmosphere. When only moderate breezes blow in the street, a gale is experienced at the clock dials. The tower up to the level of the clock dials is built of brick faced with marble, but the upper 200 feet is constructed of iron electro-galvanized with aluminum. The tower, of course, is unsupported above the roof of the main building. The top of the tower has a small diurnal motion accompanying that of the sun and owing to the expansion of that portion of the tower upon which the sunshine falls. All of these conditions made the installation of a tower clock of such prominence (which of course must be accurate) practically impossible, if built as a primary clock.

Mr. John S. Stevens, Chairman of Clock Committee and a member of this Institute, in view of the future installation of a clock in the tower, made a special study of tower clock mechanisms and had visited all the most prominent tower clocks in the world. From his investigations, he foresaw the practical difficulties. At this juncture, Mr. Stevens consulted me, as I had previously designed and constructed the largest clock in the world at Minneapolis, Minn., the dials being 22 feet 8 inches in diameter.

After examination of the building and tower, I under-

took the designing and erection of a time-indicating device suitable to the location and conditions, and the clock at this writing has been in operation two years. The departure from the older method is radical and will be understood by the following text accompanied by illustrations. The conditions under which such a clock must operate and the magnitude of the dials and of the hands is such that their designing becomes an engineering problem and not a horological problem. But in order to have accurate time, there must be an accurate timepiece, the construction of which belongs to the horological art. How I have combined the two will be seen by the description. In brief, the *real* clock, the accurate timepiece, serves only to put in motion and to control the tower mechanism, and there is, therefore, really no *clock* at all at the great height of the dials. The dial mechanism is operated by compressed air. The whole is based on the fundamental principle of all modern mechanisms, namely, the governing and directing of great forces by comparatively feeble ones.

Fig. 1 is a view of the City Hall in Philadelphia taken from the roof of the tall office building across the street. The form of the building is a quadrangle, with a court in the center, which covers four city blocks, two streets running through the building, one north and south, one east and west. The tower rises from the north side of the quadrangle at such a point as to be supported on east and west by the building itself. The clock dials are 362½ feet from the ground at their centers, the tower rising nearly 200 feet above this point. The astronomical clock is placed in the lowest room of the tower, which is just above the roof of the building itself. Air pipes lead from this point over 200 feet to the dial room above. These pipes also lead downward into the basement of the building, where there are air compressors operated by water for furnishing the power in emergencies, the main air compressor being operated by electricity and located in the dial room.

As the astronomical clock is the heart of the whole apparatus, my description will begin with the astronomi-

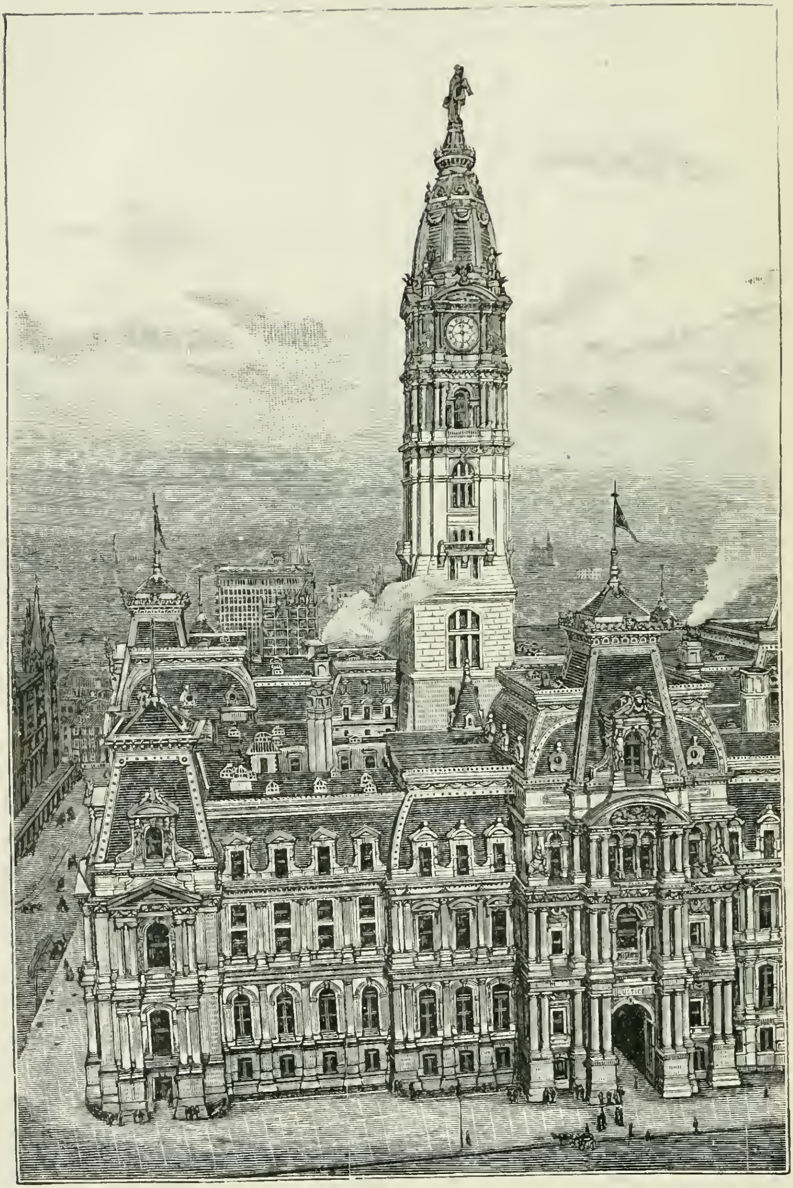


FIG. 1.—City Hall, Philadelphia.

cal clock and its immediate accessories. The best location for this clock would have been, of course, on the level of the street or below, but owing to the peculiar construction of the building, such a location could not be secured. It was, therefore, determined to put the astronomical clock in the next best position.

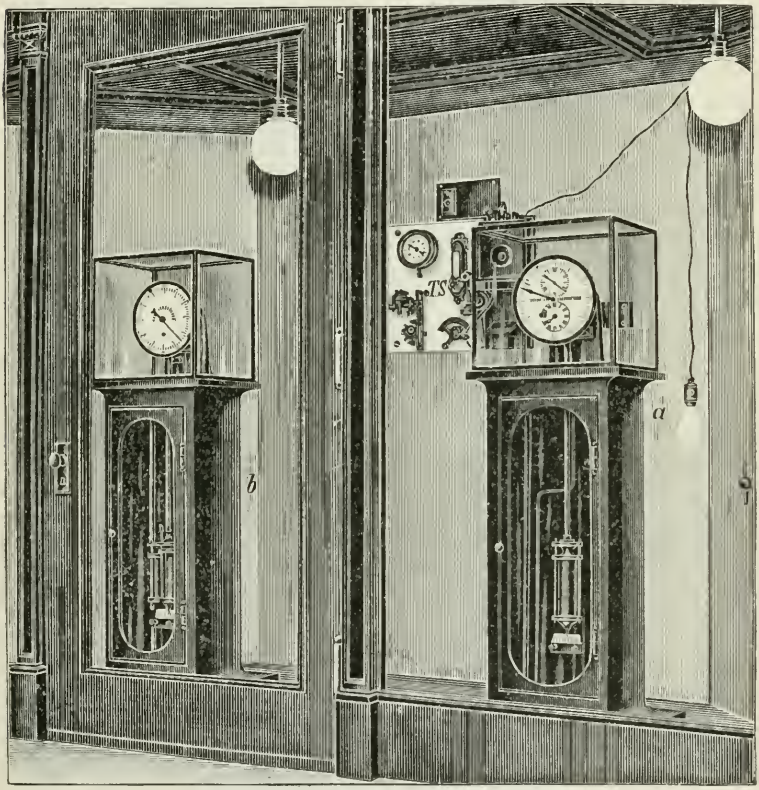


FIG. 2.—Partial view of clock room.

In the lowest room of the tower, which is on the seventh floor of the building, the walls are 13 feet thick. One corner of this room was selected and iron girders were let into the walls so as to cross the corner, and these girders furnished the foundation for the clock room, being entirely independent of the floor of the room, so that they would not take up any jar or vibration which the floor might have,

being as rigid and solid as the tower itself. Using these girders as a foundation, there was built a room of iron and copper, the foundation work being covered with marble, and the inside surface of the tower walls which came within the clock room were faced with glazed tiles. This clock room was made as perfectly air- and dust-tight as possible, by having all the glazings, as well as all the door openings, fitted with felt. This prevents the accumulation of dust, which would be detrimental to the working of the astronomical clock. The room is so tight that after six months' use not a particle of dust could be found to have settled on the clock casings in the room. A general view of the front of this room is shown in *Fig. 2*. *Fig. 3* is a cut of the astronomical clock as it appears standing alone. The clock is mounted on an iron pedestal weighing over 500 pounds. This pedestal has three adjusting screws, as will be seen, so that the clock may be brought to a perfect level at any time. The pendulum is enclosed in the pedestal. The weight also falls within the pedestal, but in a separate compartment from that of the pendulum, the object being that the weight when it falls, necessarily passing the pendulum, will not thereby influence the air friction, the air friction remaining constant at whatever position the weight may be. The dial mechanism of the astronomical clock is above the iron pedestal and enclosed in a glazed casing which may be removed when necessary. This is set upon felt strips, so as to provide against dust, as in the case of the room itself. The casing is not removed to wind the clock, but a plug is removed from the glass in front and by means of a long key the clock is wound through the hole once each month, the plug being replaced after each winding. The clock, therefore, has a double protection against dust, that is, the dust-proof clock room and the dust-proof case.

As is common with astronomical clocks, the dial has three circles, the minute circle above the center, the hour circle on the circumference of the dial and the twelve-hour circle beneath the center.

Again referring to *Fig. 2*, there appear to be two astronomical clocks. That is not the case. The clock to the

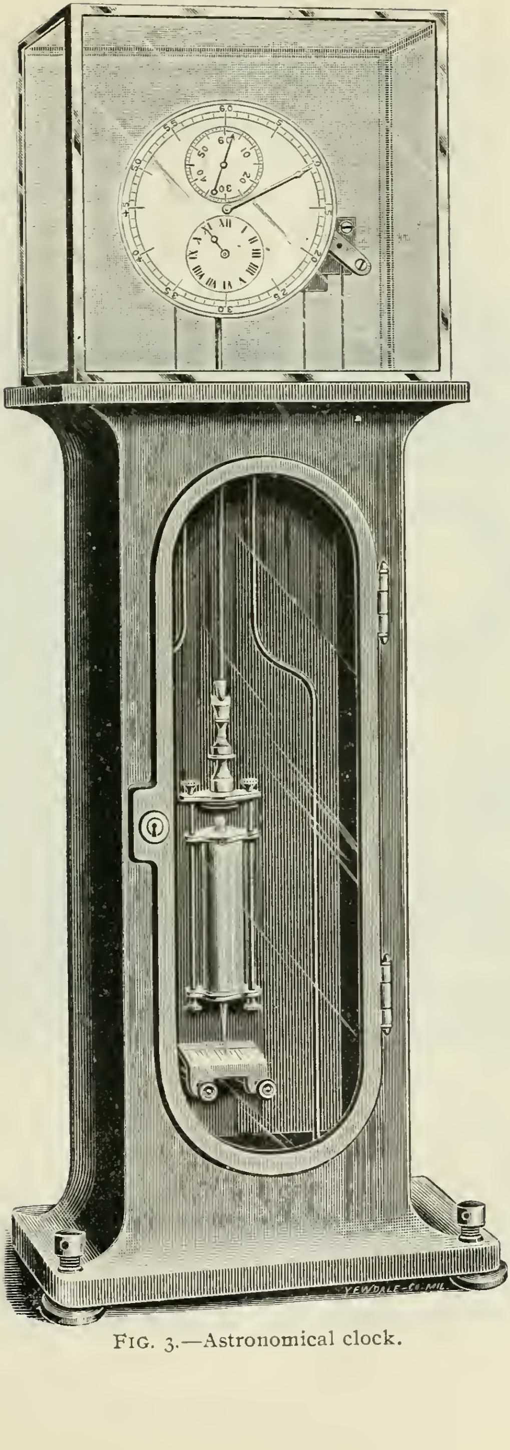


FIG. 3.—Astronomical clock.

left, marked *B*, is called an auxiliary clock. It is mounted in exactly the same way as the astronomical clock, but is of much cheaper mechanism and is used only in emergencies when it would be necessary to oil or otherwise adjust the astronomical clock. In *Fig. 3* small pipes will be seen passing up through the pedestal of the clock at the rear, and are seen on either side of the pendulum. These pipes con-

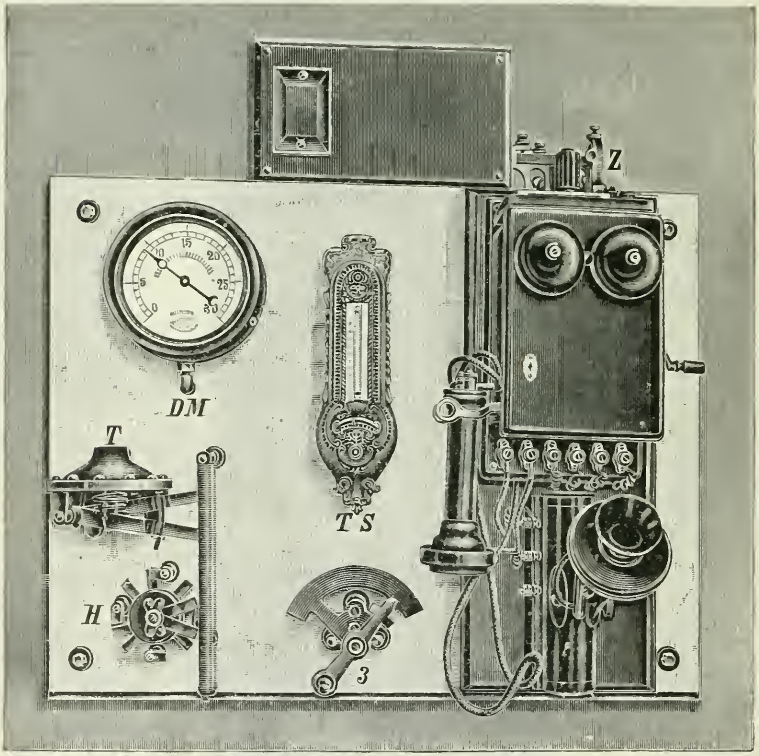


FIG. 4.—Thermostat, air switches, electric switch, telegraphic sounder, etc.

vey the compressed air to and from the clock mechanism. The function of the astronomical clock is to control compressed air, which moves the hands of the dials 200 feet above. On the rear wall of the clock room there is placed some accessory apparatus, which is shown in *Fig. 4*. *D M* is a pressure gauge which indicates the pressure used, shown in the cut to be about 9 pounds, although the exact pressure is

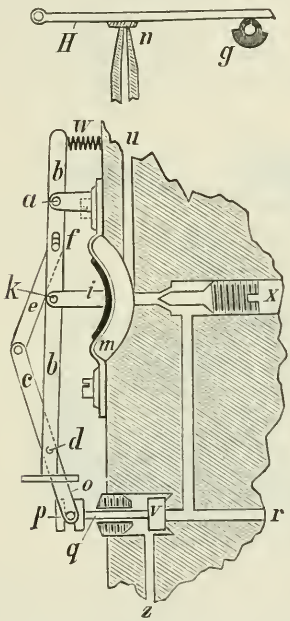
immaterial. At the left is a telephone by which any desired person may be called up from the clock room, and communication may be had if necessary with the local observatory, but the time is really governed by the electrical relay *Z*, which is placed above the telephone. This electric relay is connected by direct wire with the U. S. Naval Observatory in Washington, and each day, just before high noon, the relay begins to repeat the second movements of the pendulum in Washington. Ten seconds before the meridian the relay rests, and the first click after the rest is exactly noon. This relay is made to sound so loud that it is not necessary to go into the clock room to hear it, and, of course, the dial of the astronomical clock may also be seen through the plate glass of the room. In this way it is not necessary for any one to enter the room oftener than once a month. The presence of the human body in the room for more than a few moments has been found to be detrimental. The room is so tight that the moisture given off by the human body, which, of course, is considerable, remains in the room and is detrimental to the delicate mechanism. For this reason admittance to the room is denied, even to the attendant, excepting once a month.

Handle *3* is a switch for the compressed air. From the position in which the pointer of the switch is shown, the astronomical clock controls the tower mechanism, but if the pointer be reversed to the left, the auxiliary clock controls the mechanism, and the reversal of this index is all that is required to change the tower mechanism from the control of the astronomical clock to that of the auxiliary clock, or *vice versa*. In the center of the marble slab which supports these accessories is seen a device marked *T S*. This is a thermostat, which also controls compressed air, and the compressed air in its turn controls the electric switch *H* through the mechanism *T*. In the room at one side is an electric radiator or heater, and the current which supplies it is controlled by the switch *H*. The thermostat has the function of supplying or shutting off this current at the proper temperature. The thermostat is set at a temperature of 75° F. As soon as the temperature of the room reaches this

point, the thermostat, through the compressed air, opens the switch *H* and, therefore, the source of heat is removed. When the temperature falls less than 1°, the thermostat, through the mechanism *T*, closes the switch *H*, and the electric radiator or heater again comes into action. This apparatus is so perfect that the temperature of the clock room never varies more than 1°. It is set at 75°, so as to be as near as possible to any summer heat which might enter the recesses of the clock room, and, therefore, is as warm in the winter as it gets in summer, and remains during the year at the constant temperature of 75°. This eliminates from the problem the question of temperature, which is one which has been found most troublesome in securing accurate time mechanism. This is the only astronomical clock in the world which operates under such perfect conditions.

It will be interesting to know how the astronomical clock, without interfering with its delicacy and accuracy, can operate four sets of hands, each weighing 500 pounds. I will refer to *Fig. 5*, which is a more or less diagrammatic and sectional view of the controlling mechanism. *R* is the inlet for compressed air, which is supplied by one of the vertical pipes in the clock pedestal, as before stated. This air is supplied to two portions of this mechanism, one portion to a valve marked *V* and the other to the vertical passage where there is a threaded pin valve *X*. The air which passes through this pin valve underneath the flexible diaphragm *m* passes upward through the small tube *u*, which is continued into the clock mechanism and terminates at *n*. On the second hand arbor of the clock, that is, the arbor above the center, is placed the cam *g*. The lever *H* is fulcrumed as shown and lies across the opening of the pipe *n*, so as to close this pipe when it rests upon it. During the revolution of the second hand arbor, the cam *g* one-half of the time will raise the lever *H* from the pipe *n* and leave it open. During the other half, it will be closed. The opening in the pipe *n* is larger than the opening through the pin valve *X* to the clock chamber *m*. It follows, therefore, that when the lever is removed from *n* by the cam *g*, the chamber *m* will collapse from lack of pressure. When

n is closed, the chamber *m* will expand, since the pressure passing through *X* will accumulate. These actions take place each minute, the chamber *m* being alternately repleted and depleted of air. The diaphragm itself is not much larger than is shown in the cut. The movements of this diaphragm inward and outward operate the lever *b* against the spring *W*. Connected with this lever is a toggle which operates the valve *V*. It is unnecessary to give a minute description of this movement. When the cham-



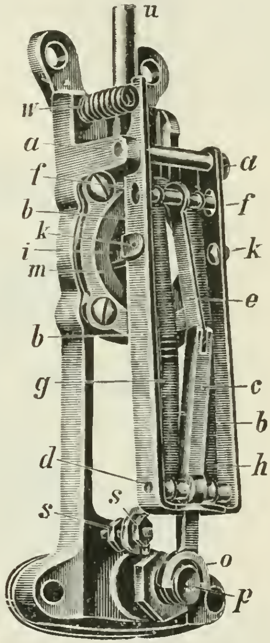


FIG. 5.—Controlling mechanism. FIG. 6.—Controlling mechanism.

ber *m* is full of compressed air, the valve *V* will be in the position shown in the cut and no air can pass by it. When, however, the chamber *m* is depleted, the spring *W* forces the lever *b* back and through the toggle reverses the valve *V* so that it closes the outlet *q* for the air, but opens the air passage at *V*, the valve itself resting to the left, instead of to the right. There is now freedom for the air to pass from *r* to *z*. *z* is the passage which leads to the air pipe which passes up the tower to the dial mechanism. All the pas-

sages and mechanisms are about the size shown in diagrammatic view *Fig. 5*. The real mechanism, however, is best seen in *Fig. 6*.

It will readily be perceived that when air is supplied through *Z* it may press upon any piston, diaphragm or any like device which may be in the dial room, and this device may have sufficient power through the proper mechanism to operate the clock hands. As the cam (*Fig. 5*) is upon the second hand arbor, it is evident that air will be supplied once each minute, and as the diaphragm *m* will be depleted once each minute, there will be a supply of air through *z* to the clock mechanism each minute and a release of this air each minute through the opening *q*.

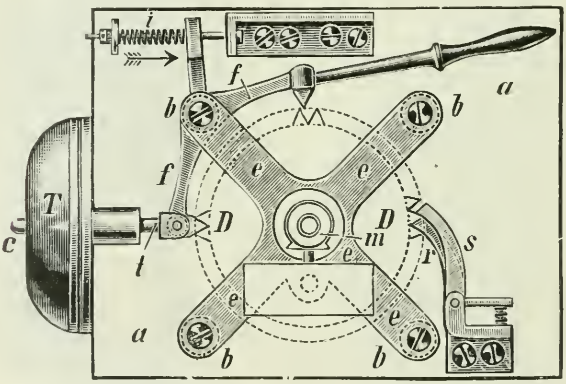


FIG. 7.—Minute mechanism in dial room.

To show how the impulses of air which are controlled and sent forward by the master clock serve to operate the dial mechanism in the tower above, we will refer to *Fig. 7*, which is a more or less diagrammatic illustration of the minute mechanism of the tower clock. The view is taken from above. *T* is a metallic chamber, concave and fitted on the inner side with a flexible woven air-tight diaphragm. The air from the master clock below sending forth impulses enters at the point *c*. The pressure of the air moves the piston having the rod *t*, and this rod *t* is fastened by a link to the anchor *f-f*, which swings in roller bearings at *b*. Studs *b-b-b-b* support the cross *e-e-e-e* which forms the

upper bearing of the shaft *m*. This shaft is prolonged upwards as seen in *Fig. 8*. Upon this shaft is a tooth wheel *D-D* having thirty teeth in the circumference. The relation of the anchor points to these teeth is such that when the anchor is pressed forward by the piston rod *t*, it forces the wheel *D* forward one-half tooth and at the same time raises the anchor point *t* from contact. By the reverse movement of the piston *T*, the first anchor point is withdrawn and the opposite one inserted, which in like manner forces the wheel *D-D* forward one-half tooth. It will be observed that this anchor effectually locks the wheel; in other words, while it rests or while in process of movement, it is impos-

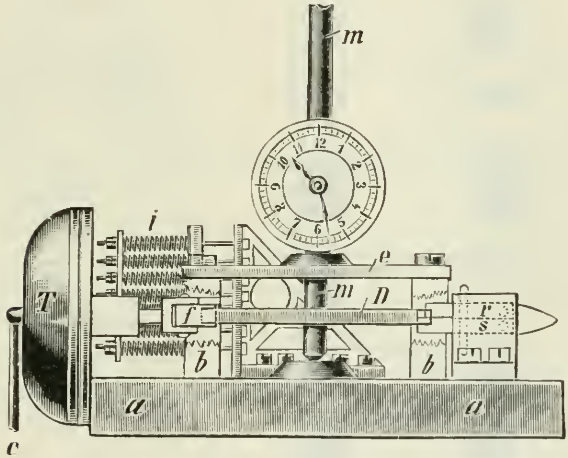


FIG. 8.—Side view of minute mechanism.

sible for the hands to fall either forward or back. In order to keep the hands in an absolutely rigid position, although there may be a movement taking place of the anchor *f-f*, pawls *r* and *s* fall into the teeth of the wheel on the opposite side from the anchor. There are two of these pawls, so that one locks at one-half of a minute and the other at the other half minute. While the piston *t* is pressed forward by the air pressure, it is pushed back by the springs *i*, of which there are seven, as shown in *Fig. 8*. The springs are divided into several, so that the breakage of a single spring will not effect the stoppage of the clock. *Fig. 8*

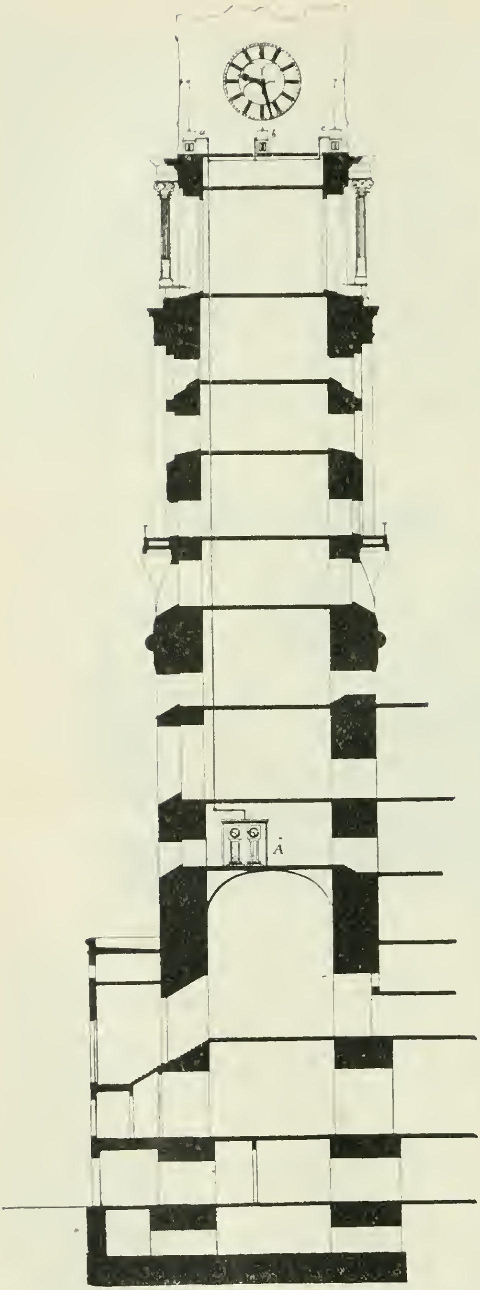


FIG. 9.—Vertical section of tower.

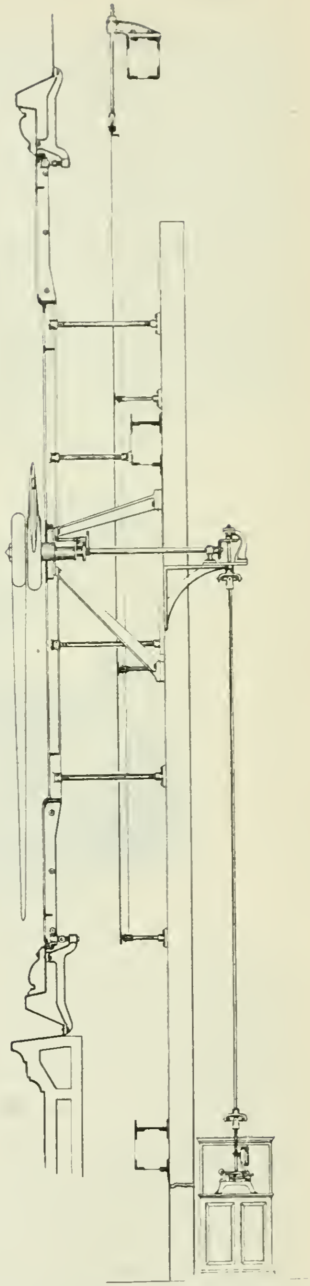


FIG. 11.—Cross-section of dial, etc.

shows the same mechanism as in *Fig. 7*, only in elevation. It will be noted that a small dial is attached to the vertical shaft *m*, so that the time may be read from this mechanism.

All four dials of the clock are not operated by a single one of these movements for two reasons: First, the impossibility of putting one center movement in the dial room, owing to the fact that an elevator passes through the center, and second, each one being independent, removes the possibility of all four dials stopping at once, owing to trouble with a single movement.

Fig. 9 shows a section of the tower from the foundation to the dial room. This shows the exact thickness of the tower walls in proportion to the interior space. It will be readily seen that at the point *A*, where the master clock is located, the walls are extremely thick, therefore substantial. As has been previously explained, the clock case *A* does not set as shown in this sketch, but is firmly attached across the massive walls and is independent of the floor. In *Fig. 9* it will be noted that the outlines of the dial room are very light. This is because above the foundation of this room, for 200 feet the tower is built of iron, instead of brick, the iron being plated with aluminum.

Fig. 10 is a plan view of the dial room, the dials themselves being marked *A*, *B*, *C*, *D*. The movements which I have described and which are placed in dust-proof cases made of oak and glazed with plate glass are shown at *E*, *F*, *G*, *H*. *I* is the elevator well. *J* is a case containing the apparatus for turning off and on the lights morning and evening (which will be described hereafter), together with the switches for the electric motors for the air compressors which are located in the same room. The outer line of *Fig. 10* is an outline of the stonework of the tower below. The dark circles are the foundations of columns which rise either side of the dials. The thin ornamental line connecting the dials at the corner is a cross-section of the ironwork of the dial room.

Fig. 11 is a cross-section of the dial, its supporting frame and of the reflecting sheet behind the dial. It shows the movement, which we have just described, in its case at the

bottom, with the vertical shaft at the side opposite the center of the dial, which shaft, by miter gears, connects with the horizontal shaft of the minute hand.

Fig. 12 is a larger, but, of course, imperfect view of the miter gearing and connections. *A* is a universal joint. *b-c* is a worm gear wheel having a key at *c*. This is for the purpose of adjusting the hands on the shaft *f*, in their relation

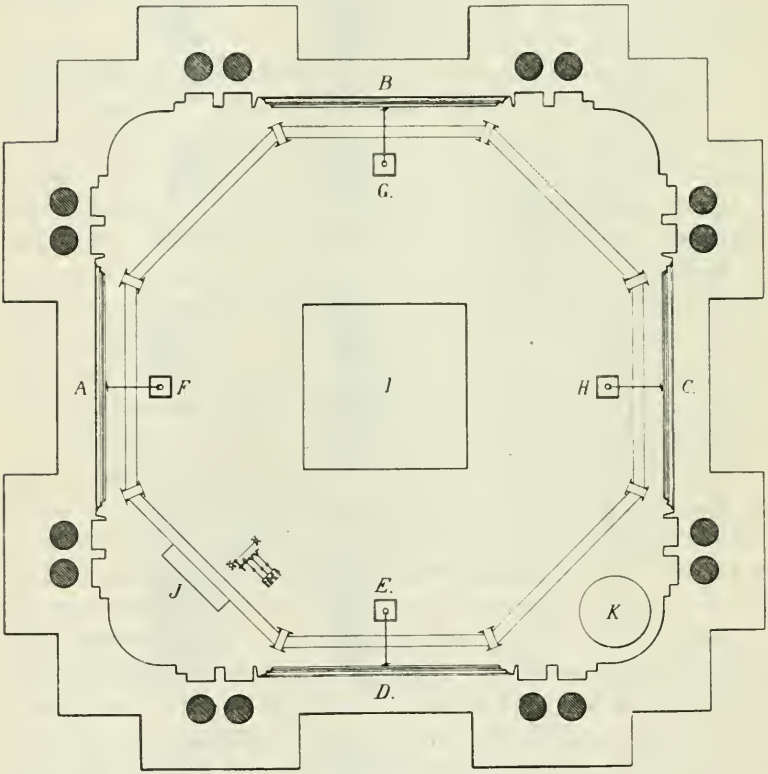


FIG. 10.—Plan view of dial room.

to the shaft *m*, so as to register them with the minute marks. This adjustment is, of course, only performed once.

The dials are the largest in the world, having a diameter of 25 feet across the centers from the extreme edges. *Fig. 13* is taken from a photograph made before the dials were

glazed. Through the openings, the city may be seen. A man stood, as shown, in one of the center circles. *Fig. 13* plainly shows the construction of the dial. It will be noted that it is sectional, having twelve separate sections bolted together, that is, for the hour sections. The minute sections are also twelve and external to the hour sections. The whole is thoroughly braced and fastened rigidly to the iron-work of the tower, which is shown by the vertical riveted sheets. The center portion of the dial is much too large for a single sheet of glass, being some 15 feet in diameter.

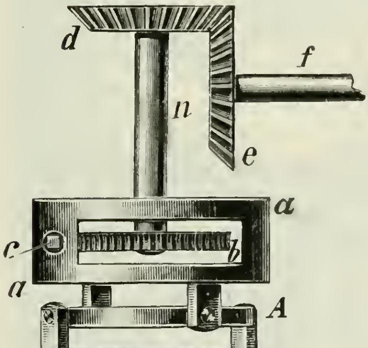


FIG. 12.—Universal joint and miter gear.

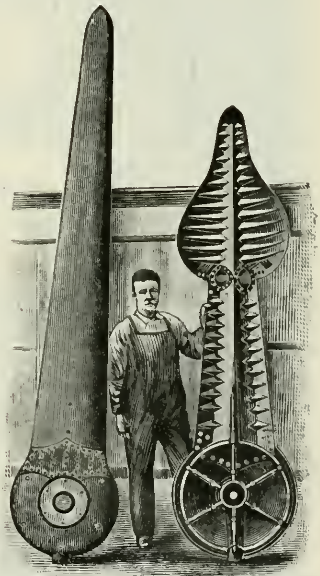


FIG. 15.—The clock hands.

It is inadvisable to section such a space radially, because the framework may be confused with the hands. By the arrangement shown, it will be seen that none of this framework is parallel with the hands at any point; consequently, cannot be confused with them; besides, the framework is comparatively light, so as not to be seen at a great distance. When seen, it is more or less ornamental. This framework is glazed with extra thick plate glass, the same being ground upon both sides. It required 2,000 feet of plate glass to

glaze these dials and sufficient glass if laid upon the ground to make a walk ten feet wide and the length of a block. The framework of the dials is made of cast iron, into which the glass is fastened with metallic clamps and bedded with elastic putty, of which it took 1,000 pounds to set the glass for four dials. The dials are perfectly water-tight. The

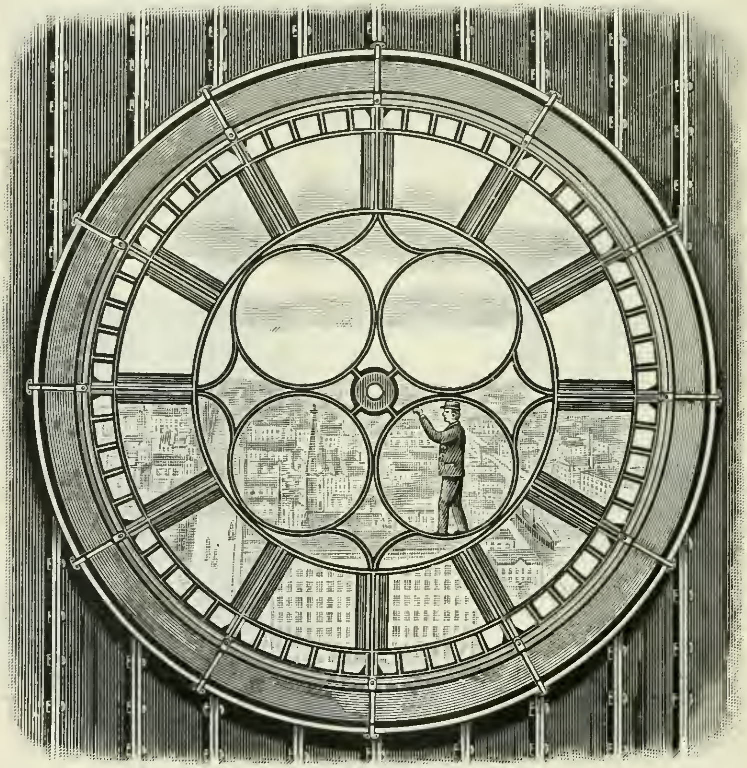


FIG. 13.—View of dial framework before glazing.

facing of the dials upon the outside is entirely of bronze, one-fourth of an inch thick. No iron of any sort appearing, all screws and bolts are made of bronze, which will endure, of course, always in any kind of weather. The dials are so far above the ground that during their construction the workmen were often in the clouds and the ironwork was

kept wet with the deposit from these clouds. Consequently, iron used exteriorly would be out of the question.

Fig. 14 is a sketch showing the dials from the outside. It also shows in sections the reflecting sheet which is behind the dial, the tower itself is supposed to be removed or transparent. It will be noted that there are no marks as 1, 2, 3, 4, 5, etc., in Roman numerals. Each block has the same value. All tower clocks previous to the large clocks designed by me have had the Roman numerals. I expected much criticism when dials were put up without these numerals, but strange to say, there is not one person in 100 who ever notices that there are no numerals, and no one has ever yet criticised the arrangement. (The first dial with such markings was designed by Arch. Kees, Minneapolis.) The truth is that these spaces and especially the numerals count for little on a clock face. No person over ten years of age would ever mistake the time of day to the extent of more than two or three minutes, if there were no marks whatever on the face of the dial. It is the hands which tell the time; therefore, they must be large and prominent. The hands of this clock are of such construction and of such importance that their description is necessary. They are, therefore, shown in *Fig. 15* taken from a photograph where the hands were set up against a wall, one of them not being completed. The minute hand is 12 feet in length and the hour hand in same proportion. It will be noticed that the hour hand is much heavier than the minute hand and of entirely different form, so that the two can never be mistaken, one for the other. The hour hand is nearly 2½ feet across at the center. These hands require heavy counterbalances, which are not shown in the cut. The sheathing of the hands is made of sheet copper, the hands being elliptical in form. The centers are supported by rigid bronze framework, which is shown in the unfinished hand. The shafts of the hands are trussed, as shown by v-shaped longitudinal braces on each half, the point of the v's on each half meeting at the center, forming an X-truss for the whole hand. The hands are so wide that supplementary transverse V-shaped trusses are also required.

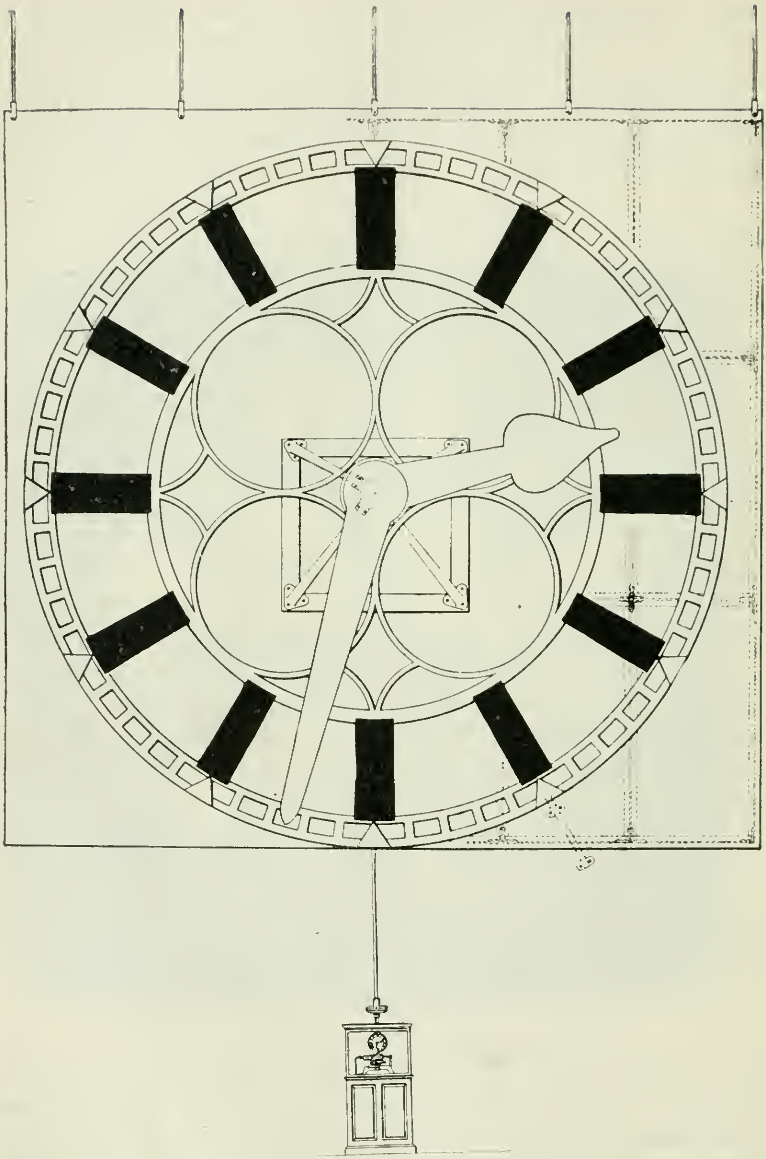


Fig. 14.—Sketch of dial, etc., from without.

The hands are made elliptical so as to oppose as little resistance to the wind as possible. Notwithstanding these hands are made as light as rigidity and durability will warrant, they weigh with the counterbalances an average of 250 pounds each, the hands for the four dials weighing 1 ton. These hands are supported by a phosphor-bronze shaft $2\frac{1}{2}$ inches in diameter and 5 feet long. As the minute arbor of a clock is always inside of the hour arbor, the minute arbor is also supported by roller bearings at each end. What is called the cluster, or the gearing which reduces the movement from that of the minute shaft to one-twelfth for the hour shaft, is rigidly fastened to the framework, the whole being supported, as shown in *Fig. 11*, by a solid frame which is about 30 inches behind the dial, having braces which go forward to support the axis and the cluster movement at the outer end. A framework of horizontal and vertical beams supports the dial against wind pressure, this support being made at twelve points. Besides being bolted to the ironwork of the tower, the edges of the dial frame are thoroughly bracketed to this ironwork.

In order that the clock may be of value for the whole twenty-four hours, of course it is illuminated, and in this particular it has some very novel features. Very many attempts have been made to illuminate clock dials properly without getting shadows and in only a few instances has it been successful. There hangs from a beam above, by means of rods, as shown in *Fig. 14*, a reflecting frame or sheet. This sheet is 25 feet square and presents a smooth surface toward the dial, the back of it being thoroughly stiffened by angle irons, as shown by the dotted lines in the figure. The same sheet is shown edgewise in *Fig. 11*, the supporting beam at the top being cross-sectioned and the studs below fasten it to the supporting beams to prevent its swinging. This sheet is first given one coat of red lead, two coats of white lead and one coat of white enamel. It is perforated for the insertion of 150 incandescent electric lights having special sockets. These lamps can be put in from the rear. This sheet hangs about 2 feet back of the dial and there is nothing intervening to form shadows.

It requires 600 electric lights, or 50 horse-power, to illuminate. The illumination is the best of any clock dial in the world. The turning off and on of these lights is entirely automatic, and the arrangement, together with some other parts, is shown in *Fig. 16*. *B A* is a four-pole rotary switch, having a capacity of 500 ampères. The four knives are fastened rigidly to the same axis as the lever *i* with a heavy ball. *T* is an expansible chamber with flexible diaphragm,

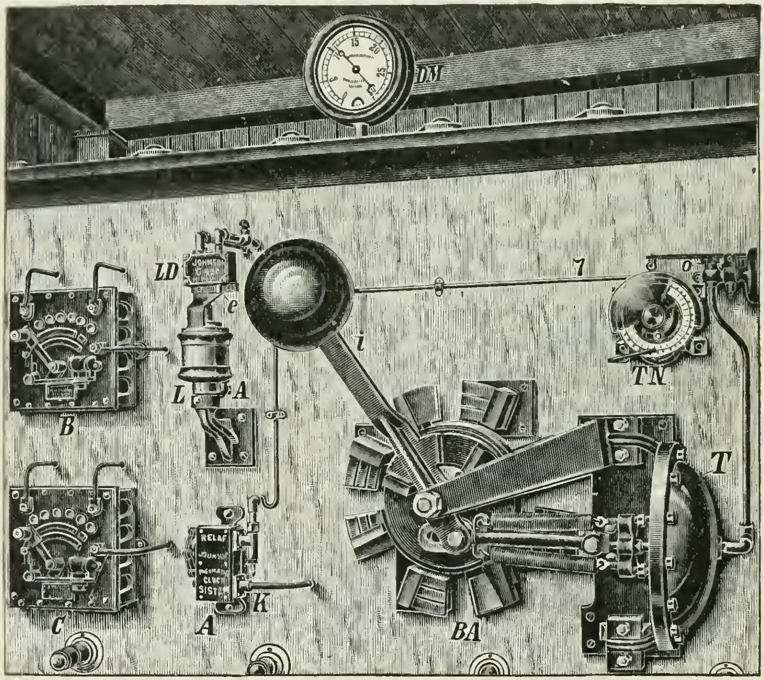


FIG. 16.—Illuminating current switch with controller.

similar to those used on the dial movements. The piston operated by this diaphragm is fastened to the lever *i*, through the connecting rod which is slotted to give lost motion, as shown. When air enters the chamber *T*, it pushes upon the piston, until the lever *i* with its ball is brought to the vertical position. As it passes from the vertical position, the weight of the ball makes it fall to the right, which suddenly makes the four connections. When

the compressed air is exhausted from *T*, the lever is again brought to center and in like manner falls suddenly, breaking connection at the four points. The air is admitted and released from *T* by the device *T N*, which is operated by the same air pressure each minute which operates the four dial movements. The index shown partially in black, partially in white is for twenty-four hours, the lighter portion representing day. The relative length of day and night are adjustable and are changed each week by the revolution of this index. The chamber *T* is filled and exhausted once in

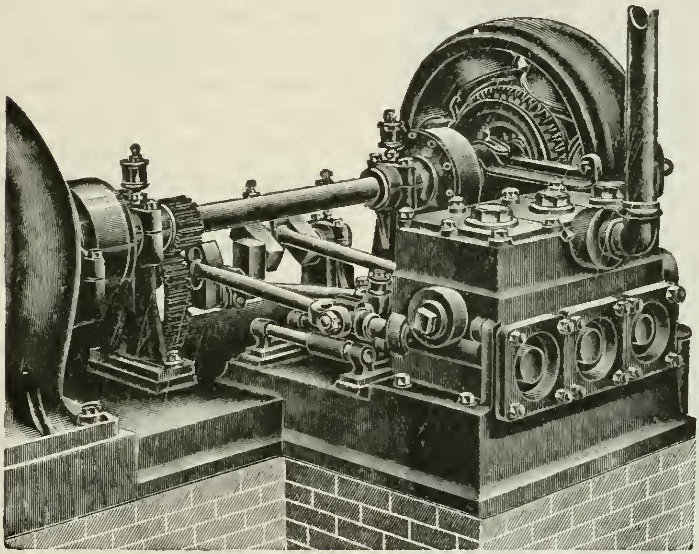


FIG. 17.—Electric air compressors.

twenty-four hours; in other words, the 600 lights are thrown in in the evening and out in the morning automatically. In the same case with this device is the city schedule for street lighting and the clock lights according to the city schedule. On the same marble slab and in the same case there are shown in *Fig. 16* other devices which it is unnecessary to describe particularly. *L D* is a governor for the air pressure, so that it never varies but 2½ pounds, the compressor stopping and starting with those limits. *B* and *C* are starting boxes for the electric motors. Having described the

dials and supports, hands, etc., I would say that the four dials, their reflecting sheets and supporting framework weigh 48 tons.

I have spoken of the compressed air being produced by electricity and that there are also hydraulic air compressors for supplementary work. I deem it unnecessary to minutely describe these devices. Suffice it to say that *Fig. 17* shows the electric air compressors which are located in the dial room, 362 feet above the ground. They are placed there for the reason that the air which is used at high elevations should be taken from high elevations to prevent unnecessary condensation. To prevent possible accident, there are two independent electric motors for these compressors. In general they work together. If there be an accident to one of them and it should stop, the other continues to do the work just the same, either one having more than twice the power required to do the work. As the electric current might be cut off at some time for some purpose, there are connected with the system and located in the engine room of the building three hydraulic air compressors with fittings, shown in *Fig. 18*. These are automatic in their action, so that they do not move when the electric air compressors are at work. Should the electric compressors fail for any reason, the hydraulic air compressors take up the work and have ample capacity. It will be noted that there are three of these. The three are con-

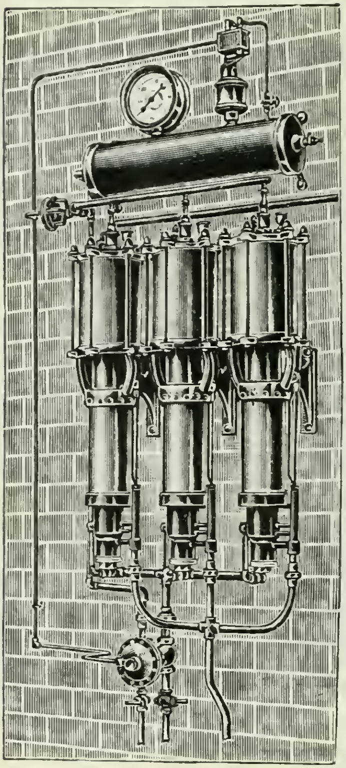


FIG. 18.—Hydraulic air compressors.

nected to two independent water lines, one of these water lines running directly from the city reservoir to the City Hall without any connections; consequently, there is very little liability of an accident happening to it. These hydraulic air compressors are so arranged that, should the water supply fail from either source, the other will do the work. Should either one of the hydraulic air compressors fail to do the work, the others have sufficient capacity. The probability, therefore, of the required air pressure failing is extremely small. As will be seen, the entire mechanism of this pneumatic clock is very simple, very positive and very durable.

This clock has now been running for two years and the derangements have been extremely few, much less than with ordinary tower clocks of much less magnitude. It is so arranged, as has been stated, that there are duplicates for every part which may fail. If the astronomical clock needs cleaning or adjusting, the work is taken up by the auxiliary clock, or *vice versa.* Owing to any derangement of the dial mechanism, only one dial needs to be stopped at a time and the failure of power is almost impossible.

Stated Meeting, held Wednesday, October 17, 1900.

ALUMINIUM AT THE PARIS EXPOSITION (1900).

By Prof. Joseph W. Richards,
Member of the Institute and delegate to the Exposition.

The five international exhibitions held in Paris, since the first, in 1855, have served as landmarks in the history of aluminium. The Palais de l'Industrie, which was demolished last year to make room for the new Art Palaces, housed the first exhibition of 1855, and in it aluminium made its first public appearance in the shape of a bar, lying on black velvet in a glass case, and labelled "L'argent de l'argile," "the silver from clay." Its production had been difficult, in a chemical laboratory, and it practically

had no price, for it was not produced then in a commercial way. That bar cost probably more than its weight in gold. But the possibilities which it stood for appealed strongly to the French mind, and the Emperor gave St. Claire Deville "carte blanche" to develop these possibilities into an industry.

The exposition of 1867 found an established industry to be represented. Deville had perfected his sodium process, and the metal was being sold commercially at the rate of $12 a pound and to the quantity of 1,000 kilograms (1 long ton) a year. It was exhibited as sheets, wire, foil, manufactured goods, polished and engraved, helmets, field-glasses, telescopes—in short, for such articles in which lightness was a prime consideration and cost secondary. The important alloy with copper-aluminium bronze was then shown for the first time.

The 1878 exhibition marked only a moderate expansion of the industry. The yearly output had nearly doubled, but the selling price was the same, and the assortment of goods made from it was hardly larger than in 1867. In short, the industry was nearly at a standstill; the limit of applications of the metal at the price at which it could be furnished by the Deville process had nearly been reached. Many of the expectations which were born of the previous exhibit had been disappointed, and but few new ones realized.

The 1889 exhibition marked a period of revolution in the industry. Castner and Netto, by new and ingenious processes, had made metallic sodium, the reducing agent of Deville's process, at a greatly reduced cost, and had thereby largely reduced the cost of producing aluminium. New life was thus put into the industry, the yearly output had increased to 71 tons and the selling price of the pure metal had decreased to less than $5.00 per pound; in fact, that very year it fell to nearly half that figure. Besides this, the electric processes of Cowles Bros. and of Héroult were furnishing aluminium in copper and iron alloys, but not the pure metal, at even lower prices.

The industry was finely represented at that exhibition,

as befitted its rapidly-increasing importance. The French Deville process, and the two new Castner and Netto processes, were large exhibitors, and the Cowles alloy products were shown. The features of this display were the large masses, ingots, sheets, etc., of pure metal, the largest quantity of aluminium ever brought together in one place up to that time. The uses of aluminium in making solid steel castings, aluminium brass, bronzes and light alloys of hardened aluminium, were among the novelties.

The last year of the century finds the industry upon an entirely different basis. From an annual production of 70 tons it has risen to the relatively enormous figure of 7,000 tons; from a price nearly $5.00 a pound, to the almost incredible figure of 30 cents. The seeds of this revolution were already germinating in 1889, for in that year pure aluminium made electrolytically by Hall in America, and Héroult in Europe, began to undersell the product of the sodium processes, and two years later the sodium processes were distanced and driven out of the business. The pure aluminium shown in 1889 was all made by the sodium process; that shown this year was as exclusively electrolytically produced.

It is almost needless to say that this decrease of price to less than one-tenth of its value in 1889 has been the prime cause of the great demand for the metal. Every decrease in price has opened up the way for larger and novel uses. Many an experimenter has reported of aluminium: "It is most admirably adapted for this purpose, and *when its price shall have been reduced*, etc., etc.," and has waked up a year or so later to the fact that his hoped-for reduction of price had occurred and that the application he had discovered was then possible. The same is true now, as then; possible uses for large quantities of aluminium are now known, which the probable reduction in price during the next five or ten years will convert into actual uses.

Such being the present facts with regard to output, prices and applications, we can state with exactness that the aluminium industry is now, at the end of the century, upon a strictly normal commercial basis. Aluminium is now as really

a metal of every-day life as silver, nickel, mercury, copper, brass, tin, zinc, lead or iron, though not to the same degree as several mentioned. In the United States, in 1898, only pig iron, copper, lead and zinc were produced in greater quantity than aluminium, and only pig iron, copper, lead, zinc, silver and gold surpassed it in value of output. Nickel, mercury, antimony, bismuth and tin were all surpassed. When we wish to make a given object in metal, it can be made cheaper in aluminium than in anything else, excepting zinc, lead or iron; brass, copper and all the other metals are dearer.

Bearing these facts in mind, it can readily be understood that a complete exposition in one or even in half a dozen exhibits of all the present uses of aluminium was not to be expected. The aluminium exhibit was in reality scattered through all parts of the immense exhibition. In electrical apparatus it was frequently used in place of copper; in the machinery exhibits its use was general in parts of light-running machinery, and frames and cases of auto-vehicles; in optical, photographic and general physical instruments the applications were so general as to defy enumeration; while possibly one-half and probably a still greater proportion of all the steel exhibited and all the steel used in and around the exhibition had had aluminium used in its manufacture to secure soundness of the ingots.

The special exhibits of aluminium represented, therefore, only a fraction of the almost innumerable applications to which aluminium has really attained; and, while mostly satisfactory in themselves, cannot be considered as alone representing fairly or completely the whole industry. By themselves these exhibits were scarcely as pretentious as those of 1889, yet they represented an industry 100 times as large. Taken together with the other applications of aluminium to be seen all over the exhibition, they give an adequate idea of the extent to which aluminium has entered now into daily use.

The firms now producing aluminium are the Pittsburgh Reduction Company, Niagara Falls; the Cowles Electric Smelting and Aluminium Company, Niagara Falls;

the British Aluminium Company, at Foyers, Scotland; the Aluminium Industrie Actien Gesellschaft, at Neuhausen, Switzerland; the Société Electrometallurgique Française, at La Praz, Savoy; the Société Industrielle de l'Aluminium, at St. Michel, Savoy. This year will also see put into operation a new plant of the Pittsburgh Reduction Company on the St. Lawrence River, Canada, and two new plants of the Neuhausen Company, one on the Rhine at Rheinfelden, Germany, the other at Lend-Gastein near Salzburg, in Austria. The establishments already in operation have capacity of 34,000 horse-power, capable of producing 7,000 tons of aluminium a year; with the additions referred to, the totals will be 47,000 horse-power and 10,000 tons annual capacity.

The exhibits in detail were as follows:

The British Aluminium Company, of London, had two large exhibits, the one on the ground floor dealing more with the crude metal, the one on the first floor with manufactured articles. Besides a fine display of sheet, rods and wire, objects of special interest manufactured by various British firms were shown. There was a large still, with hood and condensing apparatus, by Storey & Sons, built for use in distilling acetic acid. Several of these are in use in England, doing satisfactory work. The workmanship was very good. A portable water sterilizer, specially designed for army use, weighing 25 pounds and capable of producing 200 gallons of good drinking water daily. Some of these have been put to use in South Africa this year. A Derby firm showed a dog-cart with aluminium body and shafts, and spider-like steel wheels, which was a miracle of lightness combined with adequate strength. Mr. Chatterton, of the Madras Industrial School, sent three large vases and a fine panel, in Indian repoussée style, which were models of fine workmanship and artistic design. The Indian workmen take very quickly to aluminium in place of brass and copper, and the manufacture of culinary utensils for native use is assuming large dimensions. Various other British firms showed hardware, furniture trimmings, ecclesiastical furniture and many other lines of manufactures, all of excellent workmanship.

The firm received a gold medal, and a silver medal, in addition, was awarded to the managers of each of its four works.

The Société Électrometallurgique Française, whose works is at La Praz, Savoy, had the next most important exhibit. Besides the usual articles to be expected, were to be seen many novelties. Samples were shown of the military equipments adopted by the French army, some of which had seen severe service in Madagascar. Automobile castings for frames, motor cases and wheels were very much in evidence; also a motor carriage body of sheet metal weighing only 45 kilos. There was a good display of electric cables for power transmission; also various patterns of sleeves for connecting and joining rods and cables. A large funeral wreath of stamped leaves, laurel and oak, painted, recalls a European custom which is unfamiliar here. The making of such aluminium wreaths has grown to a considerable business in France and Italy.

The Société de l'Aluminium, working the Hall process at St. Michel, Savoy, as also the Pittsburgh Reduction Company in America, and the Swiss Society at Neuhausen, were but meagerly represented.

Aside from the above-named producers of aluminium, many users of the metal in particular ways were exhibitors. In the line of culinary utensils, the Griswold Manufacturing Company, of Erie, Pa., and the Wagner Manufacturing Company, of Sidney, O., fittingly represented the great interest which Americans take in this most practical application to every-day life. In electrical appliances, many firms in the electrical department showed switchboards, motor frames, motor cases, lamp shades, reflectors, search-lights, etc. In the department of scientific instruments, its use was general for balances, field glasses, telescopes, theodolites, photographic cameras, and parts of many delicate instruments. Mr. Levy, of Philadelphia, used it exclusively in the construction of his apparatus in which he etched plates by his acid-blast process, using dilute nitric acid. Chardonnet's machine for making artificial silk was constructed largely of aluminium for the same reason, since the

nitric acid used corrodes almost every other metal which might be used. Escher, Wyss & Co., of Zurich, showed a small aluminium naphtha launch and engine parts. Their work was solid and durable, but lacked finish.

Maxime Corbin, of Paris, showed some remarkably fine large castings for parts of auto-vehicles and motor mechanism. For instance, a dynamo frame complete, weighing 185 kilos (407 pounds), a cannon carriage trailer weighing about half as much, for a mountain field-piece. His large dynamo pulleys are claimed to be lighter and stronger than wood, and do not slip. This foundry turns out seven tons of castings a month, the larger part of which are for electrical and automobile purposes.

Japy Frères & Co., of Paris, showed a large assortment of army equipments; and E. Legros, of Paris, culinary utensils. Many other small firms displayed miscellaneous articles.

A distinctive feature of the present state of application of aluminium is the development of the hard, strong, light alloys. The Albradium Syndicate, of London, showed one which is a little lighter in color than aluminium, and applied to numerous mechanical uses. The Partinium Company, of Paris, had a large display of their tungsten-hardened alloy in culinary utensils, military equipment and motor cases and frames. The castings were very clean and true, and are of great value if as strong as is claimed—50,000 pounds per square inch tensile strength. The latter claim is probably exaggerated, but it is a fact that the best of these light alloys are as strong as gun bronze, section for section, and work as easily as brass.

The Goldschmidt process of producing many rare metals by ignition of their oxides with aluminium powder was finely represented in the German section. A large case was filled with quantities of pure chromium, tungsten, manganese, and the ferro alloys with these metals, and also with titanium, boron and molybdenum. The collection was unique in its way, and shows the process to be in regular commercial application. A Philadelphia firm has recently made arrangements to work the process in this city.

In the line of working aluminium, the Heraeus process of welding aluminium deserves to be highly spoken of. It is the invention of W. C. Heraeus, of Hanau, Germany, and was represented in the German section by a collection of wires, rods, sheet vessels and urns, with perfectly welded seams. The process is operated without solder or flux of any kind, and consists, according to the inventor, in merely cleaning the surfaces to be joined, laying together, heating carefully to the temperature at which the metal commences to soften, keeping at that temperature and meanwhile hammering together to a perfect weld. The process is thus seen to be that of autogeneous soldering. The inventor lays stress on the fact that the temperature must be kept constant; that if it rises too high the metal becomes short or granular, and also commences to oxidize, which conditions defeat the welding. It is merely a question of maintaining the joint by a blowpipe at the proper temperature of incipient softening and hammering together to a weld.

The samples shown were certainly very well done, and the process opens up a new era in the methods of working aluminium.

ON THE CLASSIFICATION OF CRUDE PETROLEUMS.*

BY S. F. PECKHAM.

In the famous report made in 1855 by Prof. Benjamin Silliman, Jr., upon the petroleum of Venango County, Pa., he says, while commenting upon the different boiling points of the different fractions obtained by fractional distillation:

"The uncertainty of the boiling points indicates that the products obtained at the temperatures named above were still mixtures of others, and the question forces itself upon us whether these several oils are to be regarded as *educts* (*i. e.*, bodies previously existing and simply separated in the

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* Read at the Petroleum Congress, held at Paris, France, August 25, 1900, and revised for publication in the *Journal*.

process of distillation), or whether they are not rather produced by the heat and chemical change in the process of distillation."

Further on in the report, when discussing one of the heroin distillates, he says:

"The paraffine with which this portion of the oil abounds does not exist ready-formed in the original crude product, but it is the result of the high temperature employed in the process of distillation, by which the elements are mostly arranged."

* * * "Associated with paraffine are portions of a very volatile oil, *eupione*, which boils at a lower temperature, and by its presence renders the boiling point of the mixture difficult to determine."[1]

Previous to the date of this report the naphtha of Amiano had been examined by De Saussure in 1817,[2] and the maltha of Bechelbronn had been examined by Boussingault in 1837.[3]

Up to the time Professor Silliman made this report, petroleum or rock oil had been regarded as a species by both geologists and chemists. As late as 1859 Dr. J. S. Newbury wrote upon "The Rock Oils of Ohio,"[4] and in 1862 Dr. T. Sterry Hunt had written "On the History of Petroleum, or Rock Oil,"[5] basing his discussion on his experiences in Canada.

Still later, in 1876, Dr. J. Lawrence Smith concludes that Professor Silliman, in 1855, was the first person who observed the phenomena attending the destructive distillation of petroleum.[6]

It is now believed that Pelouze and Cahours, in 1863, examined Canadian petroleum.[7] At the same time, and later, Warren alone, and associated with Storer, confirmed the results obtained by the French chemists, and obtained by means of Warren's superior process of condensation a more complete insight into the composition of the hydrocarbons constituting American and Rangoon petroleum. These results, however, were qualitative rather than quantitative, the various substances isolated being practically the same in each of the researches mentioned.

The conclusion followed naturally that the crude oils varied in character as the proportions of the same materials varied in the different mixtures. The idea that the various substances isolated were products and not educts contributed to this conclusion.

In the memoir written in 1868 by C. M. Warren, and published after his death in 1896, Warren proceeds to criticise the results obtained by Pelouze and Cahours, Ronalds, and others, in comparison with his own, and apparently assumed that the crude material upon which these different parties worked was identical.[8] If, as has been asserted, Warren worked on petroleum from the vicinity of Titusville, Pa., and the French chemists worked on Canadian petroleum, it is not surprising that the results obtained by the different investigators were unlike.

It was my privilege, during the years from the autumn of 1866 to 1872, to be on terms of familiar acquaintance with C. M. Warren. A more delightful friend never existed; yet, he was a man who held his opinions with great firmness. He had converted thousands of barrels of petroleum from the wells of Western Pennsylvania into commercial products. He knew that these wells, though drilled many miles apart, furnished oils substantially alike. Moreover, he had made that crucial test, as he supposed; he had destructively distilled menhaden-oil soap, and obtained therefrom petroleum-like compounds. To him petroleum was petroleum, for when I took into his laboratory, in which he and Storer had conducted their now classical researches, the samples of crude petroleum that I had brought from California, he listened with an amused incredulity to my assertions that I had in the cans a new species of petroleum. It was while I was in the midst of my work that he moved his laboratory to his house in Brookline, and I was obliged to finish the work in Providence. I made frequent visits to Brookline to report progress and showed him my results. He said he had examined Professor Silliman's sample of crude California oil and obtained 50 per cent. of light oils. He admitted with reluctance that his sample had been falsified. When I triumphantly assured him that

by passing gases through Pennsylvania and California petroleums that would deprive them of hydrogen, I could evaporate the first and convert the second into asphaltum, he was still incredulous, and thought my ideas regarding the origin of petroleum expressed in 1868 theoretical, without any substantial basis of fact to rest on.[9]

Although I had no absolute proof thereof, I was firmly convinced in 1868 that the California oils consisted of hydrocarbons containing less hydrogen than was found in those from Pennsylvania. It was then impossible for me to obtain a hearing from any of those engaged in investing money in the production of oil in California. The only man who would listen to me was the late Prof. J. D. Whitney, who wanted to send me to Berlin to work the problems up with Hofmann. Professor Whitney had so exasperated the general public on the Pacific Coast by his persistent iteration of the truth regarding petroleum and other interests that they sent him and his geological survey out of the State.

In 1872 Dr. J. S. Newbury published in the *American Chemist*, II, 427, his "Notes on American Asphaltum,"[10] to which I replied.[11] He spoke of the tar springs of the Southwest as springs of heavy petroleum, while I maintained that maltha, or mineral tar, was not petroleum. Meeting Dr. Newbury, a short time after I had published my paper, he showed me his large collection of specimens of petroleum from all parts of the world, and challenged me to put my finger on any specimen, from the lightest to the heaviest, that would not mark a purely arbitrary distinction. With Dr. Newbury, petroleum was petroleum, the only difference in specimens being that some were light and some were heavy.

When, in 1880, I was engaged in collecting the statistics for my report on petroleum to the Tenth Census of the United States, I encountered two significant facts: (1) The investigators of Russian petroleum had discovered that the hydrocarbons that made up the bulk of Russian petroleum were not paraffines with the general formula $C_nH_{2n} + 2$, but additive benzoles with the general formula C_nH_{2n}; (2)

a correspondent reported that the refiners of California petroleum were not making an illuminating oil that could be sold in competition with Eastern oil, but were sending their product to Mexico, where they found a less critical market than in California.

This evidence pointed to sharp distinctions in petroleums from different localities. The wells first struck on Oil Creek and the Alleghany River produced a petroleum easily refined into naphtha, illuminating and lubricating oils; and, while the evolution of the technology of these oils required many years, the movement was along certain well-marked lines, wherein no obstacles were encountered to continued success. The process of cracking, discovered by Joshua Merrill, when working on the distillates from coal, was applied with great success to the Pennsylvania oils, but attempts to apply this method of distillation to the California oils were not found to produce corresponding results, although distillation under pressure did increase the yield of light oils.

Returning to the Pacific Coast in the fall of 1893, I was soon informed by Dr. Salathé of his discovery of the nitrogenous basic oils in the crude California oils and their distillates. This discovery gave definiteness to facts already known, and led to important results in the technology of those oils. This discovery, too, revived in my own mind convictions formed many years before, that the petroleums of the Pacific Coast were specifically different from those of the Mississippi Valley, containing different hydrocarbons, producing different hydrocarbons and requiring different treatment for their successful manipulation. This conviction led to renewed attempts on my part to persuade the owners of large interests in California petroleum to have made a careful and thorough examination of their crude material, with a view to determining the chemical constitution of the oil, the nature and value of its products, and the best methods of securing those products by treatment. These gentlemen still remained unconvinced of the value of such work.

Meantime, the value of a scientific examination of petroleum was gaining ground in Europe, and exhaustive analyti-

cal researches were being had upon Russian and other petroleums. The relation and value of these purely scientific researches to technology were gradually recognized and appreciated.

In the United States the production of enormous quantities of Trenton limestone oil, comparatively rich in sulphur, brought to the attention of both chemists and technologists problems that were both new and difficult. These problems led Prof. Charles F. Mabery to take up the investigation of the "Ohio and Canadian Sulphur Petroleums"[12] along lines suggested by the researches of Warren, but with superior apparatus, and by methods brought into use by the labors and experience of the thirty years that had intervened between 1865 and 1895.

The results obtained by Mabery led me, in a memoir published in the *Journal of the Franklin Institute* for November, 1895, to review the generic and specific relations of bitumen. In that paper, that may not be familiar to this audience, I showed that, down to the middle of the present century, the ancient, medieval and modern world had known no generic relation between solid, liquid and gaseous forms of bitumen, but had regarded natural gas, petroleum or rock oil, maltha or mineral tar, and asphaltum, as things by themselves, with neither specific nor generic relations. I then determined that such a classification is purely arbitrary, depending entirely on merely physical accidents, which in no case exhibited either chemical or geological relations. I further urged that the researches of chemists for the then last thirty years had shown that bitumens had generic relations that embraced all forms of bitumen, in the widest sense, and specific relations that embraced all forms of bitumen possessing, within a certain range, the same chemical composition. I then suggested that, while it was possible to regard all forms of bitumen, either gaseous, liquid, semi-solid or solid, as constituting the genus *Bitumen*, it was equally certain that under this genus were to be found several well-defined species that embraced in some instances only the gaseous and liquid forms, like the Pennsylvania and Ohio oils, in other cases all of the

forms, like the Canadian and California oils, with still others, like grahamite, albertite, gilsonite and Trinidad pitch, that were always solid. I further called attention to the fact that Prof. J. D. Dana had apparently regarded petroleums as rocks rather than species, as he, in his "System of Mineralogy," had inserted Warren's paraffines and isoparaffines as species, while he had also made albertite, grahamite, etc., species. I then showed that there were a number of bituminous minerals that were, strictly speaking, rocks that consisted of loose sand or rock impregnated with bitumen, the bitumen being in some cases a separate species and in other cases referable to a species that usually existed in some of the common forms of bitumen.

I then suggested names for several of these species of bitumen, calling Trinidad pitch *parianite*, the Pennsylvania paraffine petroleums, *warrenite*, the Ohio and Canada sulphur petroleums, *maberyite*, and the California nitrogenous oils, *venturaïte*.

With this long preamble, largely consisting of personal reminiscence, for which I crave the indulgence of this audience, I would suggest that the mass of materials now at the disposal of the scientific men of all nations should be arranged according to some system that shall be adequate to classify all of the materials now accumulated and sufficiently elastic to receive the acquisitions of the future.

As this subject has occupied my thoughts for many years, I may be pardoned for offering some suggestions. I believe that an adequate system must embrace all forms of bitumen and cannot be confined to petroleums alone. It must begin by creating a sharp distinction between pyrobitumens and their anthracitic residues and true bitumens and their anthracitic residues. This distinction was first made by the late Dr. T. Sterry Hunt as long ago as 1863,[13] a distinction that has been too much lost sight of, and which is fundamental. This distinction is based on the fact that coals, schists and shales with their residues are nearly as insoluble in the solvents of bitumen as in distilled water; while all true bitumens are miscible with or

almost wholly soluble in chloroform, a test that at once determines their relation to pyrobituminous minerals. The so-called asphaltic coals are not coals at all, but are the anthracitic residues of bitumens.

Having distinguished bituminous from non-bituminous minerals, the classification should, in my judgment, proceed upon the basis of chemical composition alone, either from the simple to the complex or the reverse. If from the simple to the complex, the first group or family would contain pure natural hydrocarbons, as occurring in nature, not separated in the laboratory. A second group might include compounds of carbon, hydrogen and oxygen; a third, compounds of carbon, hydrogen and sulphur; a fourth, compounds of carbon, hydrogen and nitrogen. A species should fall naturally under these groups, without regard to its physical condition, whether solid, liquid or gaseous, these physical conditions being merely accidents of occurrence, as I have elsewhere shown. Bitumens that are found to be mixtures of several of these groups, characterized by the predominance of one of them, may be classed under the group to which they are most closely allied.

In this way a classification may be effected for the purposes of pure science, and more particularly mineralogy, that can be readily modified for the purposes of technology. If it is urged that such a system is too intricate for the Petroleum Exchange, and that commercial differences exist among petroleums and other forms of bitumen generally of like composition, as, for instance, the oils of the Bradford field and those of the Lower country, I insist that commerce always has, and I presume always will, assume a lofty intelligence above the scientific world, of which the scientific world can take no note, because there are no points of contact between the two spheres of human activity.

There is, however, a limit to this divergence of interest and purpose that appears when a petroleum chemist is called upon to examine petroleum from a new locality and report upon its possible relations. It is, therefore, pertinent to inquire in what manner a new petroleum may be reported. There are now four, if not more, types of commercial petro-

leum that rank relatively as follows, not intrinsically, but in commerce:

(1) Paraffine petroleums.
(2) Russian petroleums.
(3) Sulphur petroleums.
(4) Nitrogen petroleums.

The differences in these crude oils may certainly be regarded as specific, and they have been established upon the results of very elaborate analytical researches. Perhaps for commercial purposes the bestowal of specific names upon these varieties would not be understood or appreciated, but for the purposes of the laboratory they might be.

There is, however, in view of the knowledge we now possess, one aspect of this question that can well be considered by this congress and definite action urged upon both the experts in petroleum and their clients. This aspect is the extent to which the expert or the client is justified in demanding an examination of a specimen from a new locality, which shall be made by the elaborate analytical methods employed in the researches upon petroleum conducted during the last ten years.

My own judgment is that such an examination is fundamental, for such an examination is of importance from purely commercial considerations, to determine to which of the classes above enumerated any given specimen of petroleum belongs, for the oil may be in demand as a fuel, or for the manufacture of illuminating oil, or for the manufacture of lubricating oils. For either of these purposes it cannot be denied that the paraffine petroleums easily take the lead, as it requires no argument to prove that the more hydrogen gas is combined in any given liquid the greater number of heat units a pound of it will render available on combustion. Again, if it is desired to convert the petroleum into naphtha, high-grade kerosene and reduced oils, the paraffine petroleum will yield the largest return. Again, if the design is to treat the oil by cracking, the balance-sheet will show the largest profit in the conversion of paraffine petroleums.

Chemical science has not yet shown us how to add hy-

drogen to compounds deficient in that element in any large way. In the laboratory of nature, by the alchemy of the sun, those mysterious processes go forward that rob hydrogen of its oxygen, and store it away for the service of man. I am not a believer in the chemical theories of the origin of bitumens.

If the paraffines are placed in the first rank for reasons based on pure science, the additive compounds of the benzole series should take rank as superior to the naphthenes, and they in turn as superior to the olifines, if the material is to be used simply for fuel purposes. For illumination any of them are decidedly inferior to the paraffines; if for cracking, the inferiority is still greater.

If sulphur is added by substitution to either the first or second class of petroleums, objectionable features are increased. Sulphur in equivalent proportions is greatly inferior to hydrogen as fuel. It is, however, in the manipulation of sulphur petroleums for illuminating purposes that difficulties appear. If a certain proportion of a paraffine petroleum is converted by substitution of one atom of sulphur for two atoms of hydrogen, and this atom of sulphur is afterwards wrested from its combination, the result is an olifine and not a paraffine.

It requires no argument to show that the more nitrogen an oil contains the less its value will be for fuel or illumination. The basic oils may be found in extremely small quantities even in paraffine petroleums, but when the percentage becomes large in an oil containing benzoles, and a small percentage, if any, of paraffines, the value of the products that may be obtained from such a petroleum for illumination becomes seriously impaired.

A crude petroleum is not necessarily determined as belonging *strictly* to either of these types, but it must, I think, approximate one of them. It therefore becomes of importance not only from the standpoint of pure science, but from that of commercial utility as well, to ascertain by the most careful examination the composition and relations of the various compounds that constitute the sample under examination. This course, while involving more time and

expense, is, in the end, both more economical and more satisfactory than the time-honored expedient of distilling a pint from a glass retort and dividing the distillate into fractions of certain specific gravities, but of unknown composition.

NOTES.

[1] Report on Rock Oil or Petroleum. B. Silliman, Jr., New Haven, 1855; *American Chemist*, 2, 18; *Monit. Sci.*, No. 366; *Am. Jour. Gas Lighting*, **16**, 83; *Wagner's Jahresbericht*, 1872, p. 848.

[2] *Bibliothèque Universelle*, **4**, 116; *Ann. de Chimie et de Physique*, II, **4**, 314-340; *London Jour. of Science*, **3**, 411.

[3] *Ann. de Chim. et de Phys.*, II, **64**, 141; *Jour. of the Franklin Inst.*, **24**, 138; *New Edinburgh Philos. Jour.*, 22, 97.

[4] *Ohio Agricultural Report*, 1859 (2d s.), p. 605.

[5] *Reports of the Smithsonian Institution*, 1862; *Canadian Naturalist and Geologist; Am. Jour. of Science*, II, 35, 157; *Chemical and Geological Essays*, 1875, pp. 169, 176-179.

[6] *Reports and Awards, International Exhibition*, 1876. General Report of the Judges of Group III, p. 155.

[7] C. F. Mabery, *Proc. Am. Acad. Arts and Sciences*, **32**, 121-176.

[8] C. M. Warren, *Proc. Am. Acad. Arts and Sciences*, **31**, p. 56.

[9] *Proc. Am. Philos. Soc.*, **10**, 445. *Geo. Survey California*, Geology, II, Appendix, pp. 73-90.

[10] *Am. Chemist*, 2, 427; *Chem. News* 25, 46; *Am. Journal Pharmacy*, IV, 2, 313.

[11] *Am. Chemist*, **4**, 6.

[12] *Proc. Am. Acad. Arts and Sciences*, **31**, 1.

[13] *Loc. cit.*

ELEMENTARY GRAPHICS AND GEOMETRY OF THERMODYNAMICS.

By Robert H. Thurston.

(*Concluded from p. 77.*)

Proposition 11.—If any substance is transferred from any one given thermodynamic state to another defined condition by a known path, and if the same transfer be effected by a second and different path, the difference in the quantity of heat absorbed or emitted in the two cases is measured, on a diagram of energy, by the area included between the lines representing the two paths; which area measured the difference in work done. *Fig. 7.*

Let A and B represent the two given states, and $A\ a\ B$, $A\ b\ B$ the two paths taken in the process of transfer. Then the difference in the amount of heat absorbed or emitted is measured by the area $A\ a\ B\ b\ A$, included between the paths $A\ a\ B$ and $A\ b\ B$.

For, let $A\ D$ and $B\ C$ be isentropic lines through A and B, indefinitely extended toward X; then the work done and the heat absorbed or emitted are measured, when the route $A\ B$ is taken, by the areas $A\ a\ B\ x_2 x_1\ A$ and $A\ a\ B\ C \ldots . x \ldots D\ A$. If the route $A\ b\ B$ is taken, these quantities are measured by $A\ b\ B\ x_2 x_1\ A$ and $A\ b\ B\ C \ldots . X \ldots D\ A$. The differences, both in work done and in total heat absorbed or emitted, are therefore measured by the same area, $A\ a\ B\ b\ A$. Q. E. D.

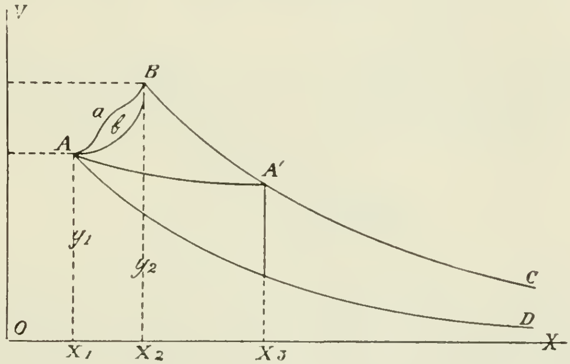

FIG. 7.—External work.

Corollary 1.—The differences in the quantity of heat demanded or surrendered by any working substance in its transfer from one state to another, by different routes, are dependent solely upon the routes taken, and not at all upon the nature of the substance.

Corollary 2.—The proposition above enunciated applies with every form of matter which can be used as a vehicle of heat-energy.

Corollary 3.—The working substance being transferred from one state A to another state B, by one route $A\ a\ B$, and being then restored to its initial state by another route $A\ b\ B$, the difference between the heat absorbed during the

one operation, and the heat rejected during the reverse change, is measured by the thermal equivalent of the work represented by the area $A\ a\ B\ b\ A$ included between the two paths of transfer.

Corollary 4.—The area, on a diagram of energy, included between the two lines of transfer $A\ a\ B$, $A\ b\ B$, and measuring the work done during such a cycle as is represented by its outline $A\ a\ B$, $B\ b\ A$, is a measure of the net amount of heat transformed into work in that cycle.

Scholium 1.—The efficiency of the cycle in which the working substance is transferred from the state A to the state B and is returned from B to A by a different path, along which heat is rejected and lost, is measured by the ratio

$$\frac{\text{area } A\ a\ B\ b\ a}{\text{area } A\ a\ B\ C\ \ldots\ X\ \ldots\ D\ A}.$$

Scholium 2.—If the line $A\ A'$ be isodynamic, and the path be $A\ a\ B\ A'\ A$, the efficiency of the cycle, of which the limits as to temperature are A and B, is measured by the ratio

$$\frac{\text{area } A\ a\ B\ b\ A}{\text{area } A\ a\ B\ A'\ x_3\ x_1\ A}.$$

Proposition 12.—In any cyclical change the net amount of heat absorbed or emitted during the cycle is measured by the area included within the diagram of energy representing the cycle, which area is the measure, also, of the work done during the cycle. (*Fig. 8.*)

Let any number of cycles be represented, including in each the points A and B, as by traversing the routes $A\ a\ B$, $A\ b\ B$, the adiabatics $A\ D$, $B\ C$, the isodynamics or isothermals as $A\ B''$, $A'\ B''$, $A''\ C$, or the isopiestic and isometric lines $A\ B'$, $A''\ C$, $B'\ A''$, or others. Then, in all cases, will the net work done, and the net amount of heat absorbed or rejected, be represented by the area included within the lines exhibiting the path of the body on the diagram of energy during the period of such a cycle.

For, let $A\ a\ B\ B'\ A$ be one of these cycles; then will the difference in heat absorbed in passing over the paths $A\ a\ B$ and $A\ B'\ B$, or the difference between the heat absorbed in

the change $A\ a\ B$ and that rejected along $B\ B'\ A$, be alike measured by the work represented by the area $A\ a\ B\ B'\ A$. If a cycle be represented by $A\ B'\ A'\ A$, the net quantity of heat demanded and transformed into work will, similarly, be proportional to the area measuring that work, $A\ B'\ A'\ A$; and similarly of any other cycles, as $A\ b\ B\ B''\ A$, $A\ B'\ B''\ A'\ A$, $A\ B''\ B'''\ A'\ A$, and of the sum, in combination, of any number of adjacent paths or cycles.

Corollary 1.—If, in any heat-engine, heat energy is transformed into mechanical energy by a change of state along a route $A\ B$, and if a less amount is retransformed into heat from mechanical energy by transfer of the substance back to its initial state A along any other route, as $B\ B'\ A'\ A$, the machine produces a net amount of mechanical work, or

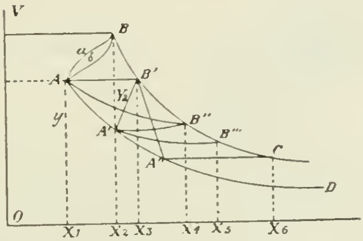

FIG. 8.—Work of cycles.

energy, by operation in the given cycle, which is measured by the area included between the two paths; or it effects a net transformation of work into heat which is the equivalent of such work.

Corollary 2.—When all heat rejected by the working fluid is discharged from the system, the total amount of heat absorbed during the first operation is expended, while the work done remains as before. The efficiency of the fluid in a heat-engine then becomes equal to the quotient of the thermal equivalent of work so done by the total heat expended, *i. e.*, the difference between heat absorbed and rejected, divided by heat absorbed.

Remark.—In all real heat-engines, heat is necessarily thus lost; since a certain amount is always rejected by the engine with the exhaust, and is carried from the system

either by the discharge of working fluid or through the refrigerator, if one be used; this heat is at too low a temperature to be utilized further in the production of work.

Corollary 3.—Internal energy remaining unchanged for any complete cycle, these principles apply equally to gaseous and other working substances, and, in all engines, the net gain or loss of heat, the quantity rejected from the system and the efficiency are determined by the amount of external work done in the cycle; the internal condition of the substance may be ignored.

Proposition 13.—The quadrilateral formed by the intersection of a pair of isothermal lines with a pair of isentropic curves encloses an area, and measures an amount of work

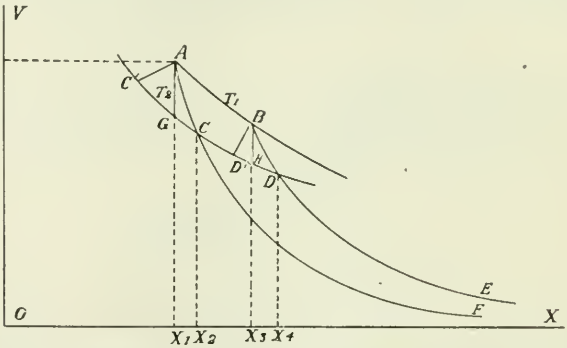

FIG. 9.—Carnot principle.

and of transformed heat which is proportional to the difference of temperature occurring during the cycle so represented. (*Fig. 9.*)

Let $A\ B$, $C\ D$, be two isothermal lines, intersected by two isentropic lines, $A\ C\ F$, and $B\ D\ E$, at A, B, C and D.

Then, in any cyclical change, such as $A\ B\ D\ C$, A or the reverse, will the extreme range of temperature be measured by the difference $T_1 - T_2$, of the temperatures of the substance when traversing the paths $A\ B$ and $C\ D$, and the area $A\ B\ D\ C$ will be to the total area, $A\ B\ D\ E \ldots X \ldots F\ C\ A$, as the net energy expended or received, and the net amount of heat absorbed or emitted by the substance is to the total heat absorbed. But these quantities of work and heat are pro-

portional to the absolute temperatures at which absorption or rejection of heat takes place, and the areas described thus measure alike differences of mechanical energy and of absolute temperature. Hence the area $A\ B\ D\ C$ is to the total area $A\ B\ D\ E \ldots X \ldots F\ C\ A$ as the difference of temperature, $T_1 - T_2$, is to the initial temperature T_1, and for such changes we have as measuring the ratio quantities of heat,

$$\frac{A\,B\,D\,C}{A\,B\,E \ldots X \ldots F\,C\,A}.$$

Also, the area, $A\ B\ x_3\ x_1\ A$, measures the heat converted into work during the expansion from A to B at the temperature T_1; the area, $A\ B\ D\ C$, measures the diminution, in amount of work so transformed, due to the difference of temperature $T_1 - T_2$; and the amount of this variation is equal for equal increments, or decrements, of temperature, and is thus proportional to the total difference of temperature, and of heat absorbed or emitted, along the two isothermals.

Hence the area, $A\ B\ D\ C$, is proportional both to the difference of temperature and of heat transformed.

Corollary 1.—The efficiency of fluid in a heat-engine working through a cycle represented by two pairs of lines intersecting, the one pair being isothermal, the other isentropic, is measured by the ratio,

$$\frac{H_1 - H_2}{H_1},$$

of the difference of heat absorbed and emitted, along the two isothermals measured from zero, to the total heat present, in the working substance, at the maximum temperature.

Corollary 2.—The efficiency of such a cycle is measured by the ratio,

$$\frac{T_1 - T_2}{T_1},$$

of the difference of extreme temperatures to the maximum temperature.*

*This cycle has already been described as "Carnot's Cycle," its efficiency having been first deduced by Sadi Carnot (1824).

Proposition 14.—The maximum efficiency of any cyclical thermodynamic operation, occurring in a heat-engine, is obtained when the absorption of heat by the working substance takes place wholly at one constant temperature, and rejection occurs wholly at a lower constant temperature, the diagram of energy representing the cycle being composed of a pair of isothermal lines connected by a pair of adiabatic, or isentropic, lines.*

For, in such cycles, the work done by transformation of heat is measured by the area included within the quadrilateral formed by the bounding isothermal and isentropic lines; this area is also a measure of the heat transformed into mechanical energy, and is proportional to the range of temperature worked through. The total expenditure of heat, taking place, as it does, entirely at the higher temperature, is proportional to the maximum absolute temperature.

But the maximum total effect is produced when all the heat transferred is so transferred with maximum range of temperature; and this occurs when all heat is received at the maximum temperature, and all heat rejected is emitted at the minimum temperature, no transfers taking place at intermediate temperatures; this cycle is one in which expansion during the period of absorption of heat is isothermal, and when the compression with emission of heat is also isothermal, the one process taking place wholly at the maximum, and the other wholly at the minimum, attainable temperature.

Corollary 1.—The cycle of maximum efficiency of fluid, in the heat-engine, is a Carnot cycle, and all heat is received at the maximum temperature, while all heat rejected is discharged at the minimum temperature, the transfer from isothermal to isothermal being effected by isentropic or adiabatic expansion, or by some other system of transfer, without final gain or loss of heat.

Corollary 2.—The maximum efficiency of fluid, in the perfect heat-engine, is a function of temperature only and is independent of the nature of the working substance.

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*This is "Carnot's Law."

Corollary 3.—The maximum efficiency of fluid in any perfect heat-engine is attained when expansion from the maximum temperature occurs adiabatically, or isentropically, down to the "back pressure," *i. e.*, to the temperature of the condenser, or to that due the atmospheric pressure, accordingly as the engine is condensing, as often with vapor engines, or non-condensing, as with air and other gas engines.

Corollary 4.—If, in the transfer of the working substance from isothermal to isothermal, the change is produced by abstraction of heat instead of isentropic expansion, and by restoration of an equal amount of heat instead of by isentropic compression, the net loss in the two transfers being *nil*, the efficiency remains a maximum, and equal to

$$\frac{T_1 - T_2}{T_1}.^*$$

Corollary 5.—Cycles in which the bounding lines are a pair of isothermal lines, intersected by any pair of isodiabatic lines, along which transfer is effected by the abstraction and restoration of heat energy from and to any reservoir of heat, are cycles of maximum efficiency; and in all such cycles the efficiency and the work done are the same when working between the same limits of temperature.

Scholium 1.—The lines representing transfer from isothermal to isothermal by the use of a regenerator approximate to the isodiabatic form as the regenerator approximates perfect efficiency in storing and restoring of heat.

Corollary 6.—The character of the isodiabatic lines adopted where regenerators are employed, whether lines of constant volume, of constant pressure, or other, or if isentropic transfer occurs between isothermals, has no effect upon the efficiency of the cycle; all give maximum efficiency if the other pair of bounding lines are isothermals of maximum and minimum temperature, the heat absorbed being then proportional to the maximum absolute temperature, that rejected to the minimum temperature, the net work done to the difference, and the efficiency measured by

* The action described would be that of a perfect "regenerator."

the ratio of the range of temperature divided by the maximum.

Scholium 2.—The "regeneration" has no effect on maximum efficiency, but may be so applied as to alter the method of isodiabatic transfer of heat and thus to reduce the volume and weight of the engine of which it forms a part.

Corollary 7.—The Carnot cycle is "reversible," *i. e.*, the operations indicated being reversed and performed in the opposite order, the effects are similarly reversed, the work is converted into heat in precisely the proportion in which, in the direct operation, heat energy is transformed into work.

Corollary 8.—All heat, in such cycles, is either transformed or it is transferred from the one to the other limit of temperature, and rejected at the final temperature.

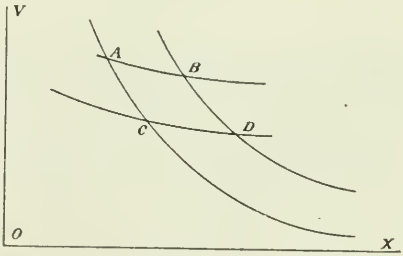


FIG. 10.—"Letting down" heat.

Scholium 3.—The maximum efficiency of the heat-engine is a function of temperatures of receiving and rejecting heat, solely.*

Proposition 15.—In every cyclical change in which heat energy is developed by transformation from mechanical energy, or the reverse, such change is accompanied by a transfer of a definite quantity of heat energy from a lower to a higher temperature, or the reverse (*Fig. 10*).

Let $A\ B\ D\ C$ represent a Carnot cycle in which the area $A\ B\ D\ C$ measures the amount of heat and work transformed between the temperature T_1 of the isothermal $A\ B$

*This conclusion is thus reached by another of several distinct lines of deduction.

and the temperature T_2, of the isothermal $C\ D$, the transition from one to the other occurring by the isentropic lines, $A\ C$, $B\ D$. Then will a definite quantity of heat be, at the same time, transferred from the temperature T_1 to the temperature T_2, or from T_2 to T_1.

For, if the course taken be $A\ B\ D\ C$, an amount of heat measured by the area $A\ B\ D\ C$ will be transformed by doing work, and all heat not so transformed and deducted from the total quantity supplied at the temperature T_1, up to the point C, will remain in the form of heat. But, during the process, rejection of heat occurs along $D\ C$ of all heat of compression and at the temperature T_2. The total heat supplied along $A\ B$ is proportional to the temperature T_1, and the quantity rejected is proportional to T_2. The proportion converted into work is

$$\frac{T_1 - T_2}{T_1},$$

and the part remaining,

$$\frac{T_2}{T_1},$$

is rejected at the lower temperature untransformed.

Similarly of any other cycle; the heat transformed into or out of mechanical energy is measured by the area $A\ B\ D\ C$ enclosed by the lines representing the cycle, while all other heat supplied is rejected at lower temperature, or, with the reverse process, all heat not received as transformed work is received in the form of heat at a temperature higher than that of supply.

Scholium.—The proportion of heat rejected in the Carnot direct cycle is the same whether transfer from isothermal to isothermal occurs isentropically or isodiabatically by means of a perfect regenerator.

Corollary 1.—A given amount of work being done in the Carnot cycle by the transformation of a proportion

$$\frac{T_1 - T_2}{T_1}$$

of heat, and with rejection of the proportion

$$\frac{T_2}{T_1}$$

as sensible heat, the reversal of the operation yields unity of heat by the expenditure of the fraction

$$\frac{T_1 - T_2}{T_1}$$

of its mechanical equivalent in work.

Corollary 2.—That cycle of the Carnot type which rejects most heat when worked directly is the most economical cycle when reversed for the purpose of obtaining heat from work.

Corollary 3.—Transformation of energy into heat by means of the Carnot cycle is an efficient method of produc-

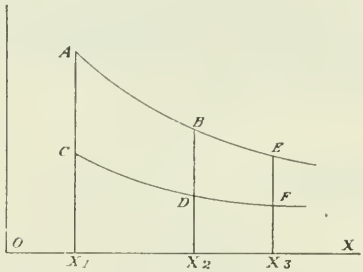


FIG. 11.—Ordinates of adiabatics.

tion of heat of high temperature in an elastic fluid, since it yields unity of heat by the expenditure of but

$$\frac{T_1 - T_2}{T_1}$$

parts of its equivalent in mechanical energy.*

Proposition 16.—In any pair of adiabatic or isentropic lines, obtained for any given gaseous substance, the ordinates at equal volumes are continually proportional. (*Fig. 11.*)

Let the lines $A\ B$, $C\ D$ be isentropic or adiabatic; then if ordinates $A\ C\ x_1$, $B\ D\ x_2$ and $E\ F\ x_3$ be drawn, intersecting the curves, the ratios of the ordinates will be equal and

$$\frac{A\ x_1}{C\ x_1} = \frac{B\ x_2}{D\ x_2} = \frac{E\ x_3}{F\ x_3}; \quad \frac{A\ C}{A\ x_1} = \frac{B\ D}{B\ x_2} = \frac{E\ F}{E\ x_3};$$

$$\frac{A\ x_1 - B\ x_2}{A\ x_1} = \frac{C\ x_1 - D\ x_2}{C\ x_1};$$

* This principle was recognized by James Thomson.

and the variations of pressure, as well as the actual pressures, are proportional.

For, the areas $A\,B\,E \ldots X \ldots x_1\,A$, and $C\,D\,F \ldots X \ldots x_1\,C$, are proportional to the total intrinsic energies of the substance at the pressures $A\,x_1$, $C\,x_1$; and these areas and energies are proportional to the temperatures and pressures of the gas at A and C; and these areas are thus proportional to their ordinates at their initial points. The same is true of the areas limited by the ordinates $B\,x_2$ and $D\,x_2$, and those ordinates themselves. Since the two curves are isentropic, and, therefore, similar, the total areas are similarly varied by equal variation of volume, and

$$\frac{A\ B\ E \ldots X \ldots x_1}{C\,D\,F \ldots X \ldots x_2} = \frac{B\ E \ldots X \ldots x_2}{D\,F \ldots X \ldots x_2};$$

whence the equality

$$\frac{A\,x_1}{C\,x_1} = \frac{B\,x_2}{D\,x_2}.$$

Q. E. D.

Corollary 1.—If the fluid have the same internal energy, in any two or more different states, defined by different pressures and volumes, the work done by indefinite expansion will be the same for all cases, and the changes of pressure and of volume will be proportional to the initial pressures and volumes.

Corollary 2.—The adiabatic, or isentropic, expansion of the fluid, from different initial states of equal intrinsic energy, to any one state, given as to pressure or volume, will yield varying quantities of mechanical energy, and different efficiencies of fluid. Equal intrinsic energies do not imply equal available energy.

Corollary 3.—That initial state which, with the same intrinsic energy, will develop the greatest amount of mechanical energy, with a definitely limited expansion, is that which is marked by maximum initial pressure.

Scholium.—The efficiency of fluid, and the efficiency of engine, in any heat-engine, is made a maximum, using working substances of equal initial intrinsic energy, when that fluid is chosen which possesses maximum initial pressure, the terminal and back pressures being fixed.

Proposition 17.—The difference in the latent heat, of expansion of any substance, expanding between isometrics at constant temperatures differing by a specified amount, is equal to the difference in the mechanical work done, in such isothermal expansion, at the two given temperatures.

Let the fluid expand, at the temperature T_1, from A to B and again at T_2, from C to D, *Fig. 12.* Then will the difference in quantities of heat absorbed in the two expansions be equal to the difference in work done in so expanding.

For, the heat absorbed, in the change from C to A, plus the heat absorbed in expansion at T_1 between A and B, is equal to that absorbed in passing from C to D and from D to B, provided none is transformed into work; but let the substance work through the cycle $A\ B\ D\ C$; then will the

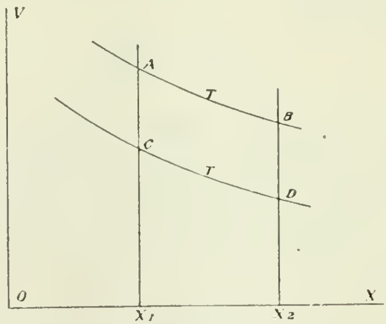


FIG. 12.—Latent heat.

net work done be $A\ B\ D\ C$, the difference between the work, $A\ B\ x_2\ x_1$, done during the expansion on $A\ B$, and $D\ C\ x_1\ x_2$, that recovered by compression on $D\ C$;

$$C\,A + A\,B = B\,D + D\,C + A\,B\,C\,D$$

for the specific heat of constant volume, measuring the variation of heat along $C\ A$ and $B\ D$, is constant, and

$$A\,B - B\,D = D\,C - C\,A + A\,B\,C\,D$$

and this transformation will be in equal amount in whichever direction the change may occur. Therefore, the work done along $A\ B$, which is equal to that done along $D\ C$, plus the difference in work done, $A\ B\ D\ C$, is also equal to that done,

in the inverse direction, along $C\,D$, plus the net work done in the cycle; and the difference in the latent heats of expansion at the two temperatures is measured by the difference in the work done by expansion at those temperatures.

Proposition 18.—The area included under any isentropic curve, indefinitely extended from any given isometric line, is dependent upon the temperature of the fluid, if gaseous, and not upon its pressure.

For, the area of the diagram so limited is dependent upon the quantity of heat-energy present in the initial state of the substance, and the amount of this energy is measured by the product of the weight of the substance into its

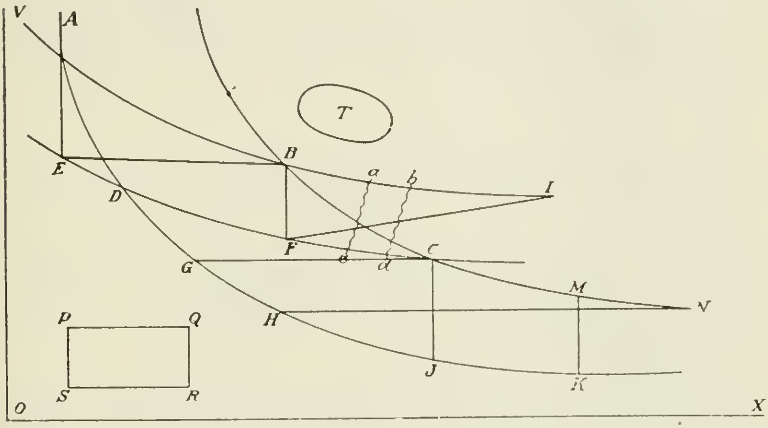


FIG. 13.—Thermodynamic cycles.

specific heat at constant volume and into its temperature, and is, therefore, independent of the pressure.

Corollary 1.—The quantity of heat absorbed in passing from any one state to another by isometric change is the same for equal difference of temperature, whatever the pressures at which the change occurs.

Corollary 2.—Two isothermal lines being drawn and connected by any number of isometric lines, the areas included between the latter and the two isentropic lines drawn through their extremities are all equal.

Proposition 19.—Whatever the form of cycle for any heat-engine, the efficiency of the fluid is measured by the ratio of

the mechanical equivalent of the work represented by its diagram to the total heat supplied to the system.

In *Fig. 13*, let the principal types of heat-engine cycles be represented by the intersection of the several lines, of which *A B I* and *E F C* are isothermal; *B C M* and *A D H K* are isentropic; *E B* and *F I*, *G C* and *H N* are isopiestic; *A E*, *B F*, *C J*, *M K*, *P S*, and *Q R* are isometric; and *T* is a cycle of indefinite and irregular form. Then, in the cycle *A B C D* the system receives heat along *A B* and rejects it along *C D*, giving maximum efficiency. In all others, similarly, the enclosed areas measure the work produced by the stated expenditure of heat, and the efficiency is the rating of the former to the latter, measured in similar units.

Proposition 20.—The isothermal and isopiestic lines for mixtures of liquids and their vapors, or for any vapors in contact with their liquids, are identical.

For, it is found, by experiment, that the boiling point of every liquid is constant at constant pressure, and the variation of the total volume of the whole mass cannot alter the pressure, so long as the temperature of the liquid is kept constant. Expansion results in vaporization at constant pressure; compression causes condensation at constant pressure.

Corollary 1.—The pressure of a vapor in contact with its liquid being a function of temperature solely, the volume of such vapor is entirely arbitrary.

Corollary 2.—The quantity of liquid present in any given weight of a mixture of a liquid and its vapor is determined by the volume occupied and by the temperature, or by the pressure which is a function of the temperature.

Corollary 3.—The density of a vapor in contact with its liquid is determined by its temperature, or by its pressure which is a function of temperature only.

Scholium 5.—The lines of transfer for the case in which change of temperature is obtained by the use of the regenerator are, in the perfect engine, isodiabatic.

Proposition 21.—The internal work done in the variation of potential energy during any change of state of any substance is measured, on a diagram of energy, by the area

included between the two extreme ordinates of the diagram and the isodynamic and isothermal lines passing through the initial point and terminating at the final ordinate.

Let the expanding body pass along *A a B* from the state *A* to the state *B*. Then will the area *A C D A*, included between the isothermal line *A C*, the isodynamic line *A D*, and the ordinate x_2, measure the amount of internal potential energy acquired; while the area *B E F B*, between the isothermal *B F* and the isodynamic line *B F*, will similarly measure this quantity, if the body is compressed by restoration to the initial volume by the same path or any other, as *B b A* (*Fig. 14*).

For, this measure is dependent on the initial and final volumes only, and is the same whether the path be *A a B*,

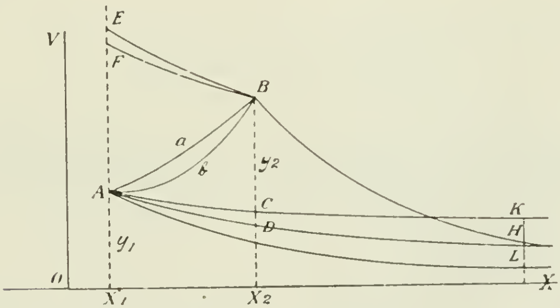


FIG. 14.—Internal work.

B b A, *A C*, *A D*, *B E*, or *B F*. But the route *A C*, being isothermal, all heat transferred is exchanged for work; along *B F*, all heat emitted comes from mechanical energy expended; along *A D*, all heat demanded for internal work is supplied from the original stock of sensible heat, and all heat absorbed is applied to the production of external energy; along *B E*, all heat emitted is derived from external work, and all variation of tension and of temperature is due to transformation of internal potential energy into sensible heat.

Hence, the difference of area *A C D*, or *B F E*, must be due to and a measure of the variation of internal potential

energy between the volumes $O\,x_1$ and $O\,x_2$, in consequence of the change $A\,B$.

Corollary 1.—The areas included between any two isothermal lines $A\,C$, $B\,F$, and two isodynamic lines, $A\,D$ and $B\,E$, having the same initial point on any one ordinate, and terminating at different points on another ordinate, must be equal wherever the initial point may be situated, the change of volume being the same for both cases.

Corollary 2.—The amount of external work done during the change $A\,B$ is measured by the difference between the area included between the path $A\,B$ and the ordinate $A\,x$, $B\,x$, and the area $A\,C\,D$, the pressures measured by the ordinates to the curve $A\,B$ being made equal to the sum of external pressure and internal molecular tension.

ANNUAL RECEPTION.

The annual reception tendered by the Board of Managers to the members of the Institute and their friends took place on Saturday evening, December 8th, in the hall of the Institute. The local membership participated very generally in the event, a conservative estimate placing the number of those in attendance at 850 persons.

The entire building, which was appropriately decorated, was thrown open for the purpose. The Lecture Room was used for a series of demonstrations, designed in part for entertainment, and chosen in part for their scientific novelty and interest. The seating capacity of the room was so inadequate that the demonstrations were repeated before two audiences, which thronged the place to the doors.

In the Reading Room, on the second floor, the managers received their guests. The executive committees of the several Sections had vied with one another in the collection of exhibits of scientific and technical interest, and the results of their well-directed efforts were in evidence upon the rows of tables, and upon the walls.

The School Rooms, on the third floor, were open for inspection and were visited by large numbers.

Luncheon was served during the evening in the alcove known as the Committee Room; and, that the fitness of things should not be violated, the musical portion of the entertainment was furnished by the latest scientific novelties, the Graphophone "Grand," and the Electro-Chord Piano. The event realized most satisfactorily the anticipations of the managers, and fully demonstrated that the members of the Institute duly appreciate these occasional opportunities for social intercourse.

The successful outcome of the reception is due to the work of a special committee of the Board of Managers, of which Mr. Henry Howson was the chairman, and to the active co-operation of the executive committees of the several Sections.

Following is a brief account of the proceedings, with a list of the principal exhibits :

Mr. Howson, Chairman of the Reception Committee, opened the proceedings in the Lecture Room with a brief address, referring to the objects which the managers had in view in arranging for this reception, and expressed the great satisfaction of himself and associates with the manner in which the members had responded.

Mr. Howson introduced President John Birkinbine, who made the following address :

Mr. Birkinbine :—" The satisfaction given two years ago by an evening set apart for greetings between members of the Franklin Institute encouraged the Board of Managers to call you together again and to ask the Committee, with Mr. Howson as Chairman, to make this event as successful as the reception of 1898.

" That the committee has fulfilled this duty the attendance to-night is evidence, and this again demonstrates that our building is much too small for the family. But it is the 'old home,' full of memories of noted men and grand achievements, and while in some particulars we criticise it for what it is, we revere it for what has been accomplished within its walls.

" It is good for as many of the members as possible to occasionally meet in this manner, for, although we have common interest in the Institute and its work, our opportunities for acquaintance, or even for recognizing who are members, are limited. Some know each other by association in the Board of Managers or by co-operation in Institute committees and Sections. We exchange a few words at monthly meetings or at the lectures, or bow to one another in the library, and our many non-resident members are practically acquainted only as readers of the Franklin Institute Journal. There are few organizations whose membership numbers 2,500 which so seldom meet as a body, for research or study are best carried forward by individuals or groups of individuals.

" The old home is thrown open to-night and the various Sections have secured interesting exhibits for your instruction and entertainment. This Lecture Room is occupied for meetings of the Institute, of its Committees, and Sections for fully seventy-five nights in each year, and we provide two courses of popular free lectures at the hall of the Young Men's Christian Association, because of our limited facilities. In this room the Committee on Science and the Arts has for many years discussed the merits of a multitude of inventions, and by the bestowal of medals and awards has greatly advanced the importance of many of these, or by its refusal to approve has diverted effort from mistaken channels.

"On the floor above is our priceless library of 52,000 volumes, most of which are now secured against destruction in a fire-proof stack room. These volumes and 37,000 pamphlets are available every week-day in the year (holidays excepted).

"The third floor, at this season, is occupied five nights each week by 240 young men who come to study drawing, machine design and naval architecture.

"The management wishes you, as members and friends of the Institute, to appreciate that an earnest effort is made to use all our facilities to the best advantage, and it also desires you to know that its intentions are constantly hampered by a limited space and a restricted income.

"Here we have an association of men and women which for seventy-six years has been active in "the promotion and encouragement of manufactures and the mechanic and useful arts," and which has won and maintains a world-wide reputation; an organization which has rendered efficient and valuable service to City, State and Nation and to the World, yet has never received, as a gift, one dollar of public money. Some of the members may suggest that certain appropriations of public funds were made, and this is true. The city of Philadelphia, twenty-five years ago, appropriated $1,000 for the expenses of an expert commission to be nominated by the Institute, and with the approval of the Mayor, to report upon the future water-supply of Philadelphia, but none of this money came to the Institute, which rendered the city gratuitous service in selecting the commission. As early as 1843, the State appropriated money to equip stations for meteorological work, and this was done and the reports were made through the Franklin Institute, but, as further State aid was withheld, the work had to be abandoned. It was revived in 1887, and two appropriations of State funds for the same purpose were made, with which an efficient weather bureau was established, and ultimately turned over in working order to the United States Department of Agriculture. There was, however, no profit in this for the Institute, nor was any of the appropriation available for its general use.

"An appropriation made by Congress more than fifty years ago for conducting the investigation of boiler explosions was applied to defraying the expenses of the investigation, to which many months were devoted; but neither the investigators nor the Institute received any compensation.

"Tests of various forms of water-wheels; investigations into the strength of materials; into the suitability of building stones; into our system of weights and measures; into smoke abatement; into the shapes and proportions of screw threads, which finally resulted in the universal adoption of the Franklin Institute standard; and the studies of the earlier forms of dynamos and incandescent lamps, were carried on by the Institute without compensation, although in some cases the work was undertaken at the request of the municipal, State or the National Government.

"The Institute has been, and is now, supported mainly from the dues of its members, supplemented occasionally by profits from exhibitions, or from gifts, principally from members. It has not, nor never has had, an endowment to produce a yearly revenue sufficient to represent any considerable portion of the cost of its maintenance.

"The Institute has received valuable gifts of books, instruments and money, the latter amounting to but $71,000, which at present interest rates would cover about 15 per cent. of the annual expenses. More than one-half of this endowment is, however, under restrictions, and while the funds may be applied to the purchase of certain classes of books, to binding, or to cover the

expense of medals, the earnings of this portion of the permanent fund are not applicable for the maintenance of the Institute.

"We gratefully remember the aid rendered by the comparatively few who, when able to do so, have given substantial evidence of appreciating the work of the Institute, and it may be that some friends may bequeath liberal sums to the Institute, but we prefer such friends should aid it now and live to see the results achieved through their generosity.

"That we are in need of a new and more commodious building has been evident for years. Our lecture hall cannot accommodate the audiences which gather to listen to the excellent presentations which compose the Institute courses. Our library is stored in contracted quarters, and our reading-room gives small space for students. Our sections, schools, etc., have grown beyond the accommodations which we have to offer, and our location, through the changes in business centers, is less desirable than formerly.

"But the policy has been to show that every part of this venerated structure is thoroughly utilized, and that we are making the best of our limited facilities. We hope to crowd ourselves out of the old home into a new one, some time in the near future.

"Surely an organization which has done so much unselfish work, the value of which is recognized throughout the world; that has educated so many young men; that has given the public access to its really excellent library, all without profit or gain, is worthy of support, especially when the help desired is to be devoted solely to extending its work.

"We are ready to be judged by what has been accomplished, in asking whether it is to the credit of our city, State or nation that an institute which, if it could be transferred across the ocean, would be handsomely endowed and housed, should be restricted in its sphere of usefulness because of a limited income.

"You members of the Institute may well be proud to wear its badge, a symbol which is respected in every American and European technical society or library, an emblem of one of the earliest and long-continued efforts to show the true brotherhood of man in co-operative research and work to benefit his fellow-man.

"Is it your wish that the Franklin Institute should keep pace with modern invention and improvement; that its lecture courses shall be maintained at the high standard established; that its library receive all the new technical publications and that its worn volumes and periodicals be properly bound; that its sections and committees be unhampered by lack of funds to prosecute investigations; that its schools continue to aid young men who, employed during the day, seek a higher education at an institution which has, in this manner, helped thousands, many of whom are now noted specialists?

"If so, then there are ways open to you. Co-operation in raising the endowment fund for which Mr. Kuhn's committee is striving, and of which the interest only is to be used for maintenance, will assist in placing the Institute in position to do all that is desired. If unable to contribute or secure contributions to this endowment, you can present the advantages of the Institute and its work to acquaintances. There are surely in Philadelphia thrice as many men and women who would be members of the Institute if it were personally presented to them, and our 500 non-resident membership, scat-

tered throughout most of the States of this country, and some also in foreign lands, can be added to if the same method is followed.

"In the absence of assurance of prospective windfalls, the duty of maintaining the Institute remains with its members, and this duty is impressed upon each individually.

"Your Board of Directors desire that the Institute shall be self-supporting. In the four years during which it has been my privilege to preside over the Institute I have found the Board earnest and enthusiastic in its work, and also generous in meeting deficits by personal subscriptions. I am sure the members do not ask the latter from those chosen to administer the affairs of the Institute, and, as this has appeared an opportune occasion to invite attention to the necessity of every one co-operating, it has been taken advantage of in the hope that this imperfect presentation will stir the pride and encourage the interest of each member and friend of the Franklin Institute to relieve the organization from a forced economy which contracts its usefulness and limits the service it can render in 'the promotion and encouragement of manufactures and the mechanic and useful arts.'"

The contributions of the several Sections are enumerated below:

Specimens of viscose silk in skeins, (*a*) unbleached, (*b*) bleached, (*c*) dyed. Fabrics made from viscose silk with cotton warp, (*a*) unbleached, (*b*) bleached. Novelty fabrics (portières) made from viscose silk in colors, with cotton warp. Artificial horsehair made from viscose. Mackintosh cloth made from rubber-viscose dough.

(Exhibited by Prof. J. M. Matthews, Philadelphia Textile School.)

A collection of the rare earths and their salts, embracing compounds of lanthanum, praseodimium, neodimium, zirconium, thorium, etc., and of the newly-discovered elements samarium and gadolinium.

(Exhibited by Dr. Waldron Shapleigh, chemist to the Welsbach Light Company, Gloucester, N. J.)

A huge furnace section of carborundum, finely crystallized.

Specimens of artificial graphite (pseudomorphs) formed by the dissociation of carborundum (silicon carbide), preserving the crystalline structure of the carborundum.

(Exhibited by the Acheson Graphite Company, Niagara Falls, N. Y.)

Carbonless manganese (96·5 per cent. Mn) made by reduction of the monoxide by aluminum.

(Exhibited by the Carbonless Manganese Company, Philadelphia.)

A collection of specimens of hides tanned with formaldehyde.

(Exhibited by Dr. Chas. S. Dolley, Philadelphia.)

A collection of ferro-alloys, embracing ferro-nickel, ferro-tungsten, ferrochrome and ferro-molybdenum, and of a new bearing-metal with 12 per cent. of lead.

(Exhibited by the Ajax Metal Company, Philadelphia.)

A collection of armor plate and other steel chips, showing the remarkable performance in speed of cutting and depth of cut achieved by the Taylor-White steel cutting tools.

(Exhibited by the Bethlehem Steel Company, South Bethlehem, Pa.)

Specimens of fire-proofed wood, and photographs of apparatus therefor.

(Exhibited by the U. S. Fire-proof Wood Company, Philadelphia.)

Moving picture machines (three movements); projecting microscope; projecting polariscope; projecting spectroscope.

(Exhibited by Williams, Brown & Earle, Philadelphia.)

Improved gas calorimeter (constant reading); improved gold assay balance distinctly sensitive to $\frac{1}{400}$ milligram (claimed to be the most sensitive balance manufactured in the United States); tintometer (Lovibond's) for recording colors and shades; X-ray tube with improved vacuum-regulating device, and device for preventing heating of platinum and blackening of inside of tube; Dewar bulbs and cylinders, plain and silvered, for liquid air; improved Spencer microscope; improved attachable mechanical stage for same.

(Exhibited by Mr. Simeon Trenner, agent for Eimer & Amend, New York, and the Spencer Lens Company, Buffalo, N. Y.)

Portable cable testing outfit; tripod d'Arsonval galvanometer; projection galvanometer; portable photometer; localization apparatus; specific gravity balance; Continental microscope, No. II; microscope for examining metals; Ryan electrometer; projection micro-polariscope; Sayen's self-regulating X-ray tube (awarded John Scott Medal by the Franklin Institute); Ayrton shunt box; Overshed testing set and generator, 500 and 1,000 volts, Queen & Co., Inc., American manufacturers; apparatus for determining sulphuretted hydrogen.

(Exhibitors, Messrs. Queen & Co., Philadelphia.)

Model of movable stairway, exhibited by Mr. James M. Dodge, Link-belt Engineering Company, Nicetown, Phila.

A large assortment of seamless cold-drawn steel tubes and cylinders, for air, steam, gas or fluids under pressure.

(Exhibited by Messrs. Janney & Steinmetz, Philadelphia.)

Electro-chord piano.

(Exhibited by Mr. George Breed, Philadelphia.)

Three sizes pneumatic chipping and caulking hammers, Nos. 1, 2 and 3; No. 8 pneumatic hand riveter for driving inch rivets; No. 7 pneumatic hand rammer, weight 20 pounds, No. 8 pneumatic hand rammer, weight 45 pounds, three styles rammer blocks; different styles chisels used with chipping and caulking hammers; rivets driven with pneumatic hammer, showing cross-section; section $\frac{3}{4}$-inch steel boiler plate, showing chips 3 feet long by ½ inch thick, made with No. 3 hammer at the rate of 1 foot per minute.

(Exhibited by the Philadelphia Pneumatic Tool Company.)

Automobile steam motor.

(Exhibited by Mr. Jas. T. Halsey, Philadelphia.)

Photographs.—Of these a large collection, principally the work of members of the Institute, was displayed about the walls of the Reading Room. The following exhibitors were represented: Wm. D. Anderson, Edward Brown, John Carbutt, Alfred Clegg, J. Logan Fitts, Spencer Fullerton, Richard Gilpin, A. M. Greene, Jr., Wm. O. Griggs, M.D., M. C. G. Grosholz, F. Gutekunst, Henry Howson, Messrs. Jennings & Sawyer, Werner Kaufmann, Frank J. Keeley, Thos. C. Martindale, Jr., Carl A. Oldach, J. W. Ridpath, Alfred Rigling, H. Ritter, Frank Roselle, Samuel Sartain, Alfred N. Seal, Thos. S. Stewart, Wm. H. Thorne, Messrs. Williams, Brown & Earle, U. C. Wanner.

W. H. W.

BOOK NOTICES.

American Telephone Practice. By Kempster B. Miller, M.E. Large 8vo, pp. x–458. New York: American Electrician Company. 1899.

The author of this work has succeeded in making a comprehensive treatise covering all phases of telephony in language free from mathematical abstrusities, so that it may be adapted to the comprehension of the average non-electrical reader in search of information. The book embraces an historical sketch of the development of telephony, in which the general principles of the art are elucidated, and a more or less elaborate exposition of the design and construction of commercial apparatus, and of the method of constructing, operating and maintaining them. W.

Municipal Public Works. An Elementary Manual of Municipal Engineering. By Ernest M'Cullough, C.E. Published by the author. Lewiston, Idaho. Second edition. 8vo, pp. 150. Paper cover. (Price, 50 cents.)

This work was originally prepared for the trustees of a California town, the intention of the author being to discuss from the engineer's standpoint, and in a thoroughly practical way, the numerous questions relating to municipal public works, with which such a body has to deal.

The several chapters treat respectively of streets, drainage and sewerage, water supply, street lighting and fire protection, plans and surveys, municipal ownership, and the city engineer. All these are treated of in a manner suited for the comprehension of the average town officer charged with the responsibility of acting on questions of town improvements. The author's opinion on the question of municipal ownership is adverse. W.

De Paris aux mines d'or de l'Australie occidentale. Par O. Chemin, Ingénieur en chef des Ponts et Chaussées, etc. Paris: Gauthier-Villars. Petit in-8, avec 111 photogravures, 9 cartes dans le texte et 2 planches. 1900. (9 francs.)

The author was charged by the Minister of Public Instruction with a mission to examine and report upon the gold mines of Western Australia, and after spending about a year in the examination of that region, he gives in the volume above entitled a summary of his observations. Inasmuch as the mining region covered by M. Chemin's itinerary is comparatively unknown, having been very little written about, his contribution to the history of the region should be of more than usual interest to those in search of such information. W.

Power Transmitted by Electricity and applied by the electric motor; including electric railway construction. By Philip Atkinson, A.M., Ph.D. Second revised edition. 8vo, pp. ix–241. New York: D. Van Nostrand Co.; London: Crosby, Lockwood & Son. 1899. (Price, $2.)

The second edition of the present work is issued under a new title, the first edition, which appeared in 1893, having been entitled "The Electric Transformation of Power." The work is written in plain, untechnical style, to adapt it to the comprehension of the non-mathematical reader, and from

the inspection that we have been able to give it, it appears to be well adapted for its intended class of readers. The revisions and additions made to this edition have brought the subject-matter up to date. W.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin, M.S., etc. 8vo, pp. 249. New York: D. Van Nostrand Co.; London: Sampson Low, Marston & Co., Ltd. 1899. (Price, $3.)

The author's purpose in this work has been to afford electrical engineers and those generally in charge of polyphase machinery a volume of information, in conveniently accessible form, bearing on the characteristics, uses and *modus operandi* of polyphase apparatus. The author appears to have done his work thoroughly well. W.

Franklin Institute.

[*Proceedings of the annual meeting held Wednesday, January 16, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 16, 1901.

President JOHN BIRKINBINE in the chair.

Present, 79 members and visitors.

Additions to membership since last month, 10.

The President made some informal comments on the facts contained in the Annual Report of the Board of Managers, printed copies of which were placed in the hands of the members. The Report with accompanying Appendices was accepted.

Dr. Henry Leffmann, by special invitation, presented a communication on "The Applications of Photography to Police and Sanitary Administration." The speaker received the thanks of the meeting, and the communication was referred to the Committee on Publications.

Mr. Arthur F. Bardwell, C.E., of New York, gave a description of the mechanical construction, operative features and capabilities of the Bardwell votometer, illustrating the subject by the exhibition of one of the machines.

The Secretary made a brief allusion to an interesting series of specimens illustrating the utilization of the wastes from the galvanizing of iron. These embraced the so-called sal-ammoniac skimmings, surface and heavy dross, the various grades of refined spelter recovered, "aluminized" zinc used in the refining process, aluminum-zinc alloys, electrolytic zinc, and samples of the final residuum, known as the "bottoms," which is subjected to distillation. The samples were exhibited by Mr. Joseph Richards.

The tellers of the annual election held this day, between the hours of 4 to 8 P.M., reported that the nominees for officers, managers and committeemen placed in nomination at the stated meeting of December 19, 1900, had received all the votes cast. They were thereupon declared elected. The tellers received a vote of thanks.

Adjourned.

WM. H. WAHL, *Secretary.*

APPENDIX.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE FOR THE YEAR 1900.

To the Members of the Institute.

GENTLEMEN :—The Board of Managers is able to chronicle another year of successful effort to carry forward the objects for which the Franklin Institute was organized and can repeat its statements of a year ago, that every section and every committee has been active, that the membership has increased and that substantial progress has been made. But it must also again call attention to the fact that the revenues of the Institute are insufficient to properly prosecute the work desired and that which may properly be expected of the Institute.

Much of the time of the Board, which could otherwise be devoted to expanding the field of its usefulness, is of necessity given to discussing means of making a limited exchequer cover the varied requirements of the library, the Journal, sections, meetings, schools, etc.

While economy is a virtue not to be deprecated, our necessities have required parsimony in some directions. The Library Committee have to reduce expenditures to the extent of denying to the members many publications which should be added to our valuable collections; sections are restricted in their work by the inability of the Board to supply funds for laudable investigations, and the Institute is thus seriously handicapped in every direction. Your Board has carefully considered each item of expenditure and is satisfied that none of the Institute funds are misapplied or wasted. The financial statement appended indicates the sources of income and exhibits the fact that the endowment funds are far from sufficient to materially aid in maintaining the usefulness of the organization.

It is essential that we keep pace with other institutions, following in the path broken by the Institute, but which have handsome endowments. And it is against such odds that we must contend without similar resources.

To be in the van with a technical library demands large expenditures for rapidly augmenting publications.

To maintain interest in the Institute and sectional meeting necessitates liberality in preparing data or exhibits.

These facts, taken in connection with the decline of interest rates, make demands beyond the available income.

Hence the Board appeals to its members to co-operate in relieving the Institute by augmenting its endowment or increasing its income.

The permanent investments and the value of our building site are valuable assets—but they are insufficient to maintain our activity as every loyal member desires it to be maintained.

This statement is presented to encourage the membership at large to assist in placing the Institute in a better financial position.

The Board does not desire to have this presentation indicate discouragement; on the contrary, the reports appended, and which are briefly summarized below, give proper cause for congratulation.

The Institute, with its building, its moderate endowment and its library, is far from being in financial difficulties.

But we cannot afford to entail our resources for temporary revenue.

To properly maintain the work of the Institute will require a larger annual income, and the statements which appear in the various reports appended will indicate that with a small outlay important results are accomplished.

These reports show that in the past year the Committee of Science and Arts considered 100 cases, and thirty-three medals or certificates of merit granted.

That two courses—12 lectures in all—were held in the Y.M.C.A. Hall.

That three night schools, viz.: a school of Drawing, of Naval Architecture, and Machine Design, were maintained.

That ten stated meetings of the Institute were held and one reception.

That there were thirty-five meetings of sections, at which a number of important papers were read, or discussions had; that 1,243 bound and 638 unbound books and more than 1,500 pamphlets, maps and charts, or 3,409 numbers were added to the library; that the membership, principally in the non-resident list, increased by nearly 200 accessions, and that a larger edition of the Journal was published than ever before; and yet, to cover this entire field of work, maintain the building in good repair, heat it, light it, etc., there was available a total of but $19,557.27.

With your co-operation in the seconding the efforts of your Committee on Endowment and in securing substantial additions to our list of resident members, the continual embarrassments of your Board, arising from insufficiency of revenue, could readily be done away with.

Appended are the data relating to the operations of the various branches of the Institute.

By order of the Board.

JOHN BIRKINBINE,
President.

PHILADELPHIA, January 9, 1901.

REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS, 1900.

Members at the close of 1899	2,151	
Number of new members elected who have paid their dues in 1900	211	
		2,362
Lost by death, resignation and non-payment of dues		75
Total membership at the end of 1900		2,287

FINANCIAL STATEMENT FOR THE YEAR 1900.

Balance on hand January 1, 1900	$107 81
Receipts	20,657 27
Payments	19,713 22
Balance	$1,051 86

ANNUAL REPORT OF THE COMMITTEE ON INSTRUCTION, 1900.

To the Board of Managers.

GENTLEMEN :—Your Committee on Instruction has to report, in reference to the popular scientific lectures which for several years have become something of an established feature, that the joint arrangement for co-operation with the Young Men's Christian Association was continued during the past year, and that, as heretofore, the outcome has proved to be notably satisfactory. The Committee has been able, as heretofore, to secure the gratuitous services of its lecturers, and the general interest and excellence of the courses has been attested by the unusually large attendance.

The Committee herewith expresses its great obligations to its lecturers for their services.

The school work during the past year has been unusually active. What is practically a new school has been started with flattering prospects of success, and all have shown an encouraging increase in the number of pupils in attendance.

There are now in active operation three night schools, the Drawing School, the School of Naval Architecture and the School of Machine Design. The last-named is an outgrowth of the School of Elementary Mathematics, founded two years ago, and, although just inaugurated, has a considerable body of pupils, and its prospects are such as to give the Committee much satisfaction.

The School of Naval Architecture, founded two years ago, also, has enjoyed a substantial growth, and the Committee hopes soon to be able to arrange for the widening of its scope to embrace the allied subject of Marine Engineering.

The Drawing School continues to maintain its reputation for thorough instruction, and has shared in the general prosperity of the schools.

The following data of attendance are presented for comparison :

	1899.	1900.
Drawing School	231	298
School of Naval Architecture	36	61
School of Machine Design	30	61

The Committee, in conclusion, is pleased to report that all those connected with the schools, directors and assistants, have exhibited the utmost zeal in promoting their interests.

Respectfully,

WM. H. WAHL,
Chairman Committee on Instruction.

January 1, 1901.

ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY FOR THE YEAR 1900.

To the President and Members of the Franklin Institute.

GENTLEMEN :—The Committee on the Library respectfully reports the following summary of the operations of the Library during the year 1900 :

	Bd. Vols.	Unbd. Vols.	Pphs.	Chts.	Designs.
Additions	1,243	638	1,498	20	10
Total additions for the year 3,409					

A decrease of 177 from 1899, but an increase of 572 over 1898, and 483 over 1897.

Total number of volumes, January 1, 1901 52,229
Total number of pamphlets, January 1, 1901 37,043

The Library also contains 2,827 maps and charts, 652 designs and drawings, 1,222 photographs, 191 newspaper clippings, 30 manuscripts.

Exchanges.—Four hundred and ninety-seven societies and publications were on the exchange list of the journal during the year 1900, an increase of ten over 1899.

The Library is consulted by a daily average of about 150 visitors, two-thirds of them in search of patents.

It is evident that the Library, with its remarkable collection of over 90,000 books, pamphlets, maps and drawings and its large daily attendance, is the most important feature of the Institute, useful as are the general and sectional meetings, the lectures, the schools and the Journal. The meetings, especially the section meetings, produce original material, the Journal brings it in a permanent form before the world, the schools teach a certain number of students; but the Library, a vast repository of all kinds of applied science, is consulted by thousands, and is used by great numbers in elaborating new material. The Journal itself, which is to the outside world the flower—yet more, the fair and substantial fruit of our whole plant—has perhaps its greatest usefulness in bringing directly, or indirectly, acquisitions and support to the Library. There is every reason, then, for making the utmost effort to supply the urgent needs of the Library.

The Library is still sorely lacking in space, as intimated already last year. Especially, the extremely valuable collection of over 37,000 pamphlets lies practically useless, without shelving, in the third story of the part of our building that is not fire-proof; and proper accommodation for the invaluable collection of drawings and charts is still lacking.

We would strongly urge the advantage of making room for the pamphlets by taking the Seventh Street end of the drawing school, above the present book-stack. The space so taken would be ample for the pamphlets, and could be made practically fire-proof by a brick wall between it and the rest of the school, and by a corrugated iron ceiling below the slate roof above. The fire-proof character of the main book-stack would not be diminished, for the new room would be entered by way of the school stairs, and there would be no opening to it from the stack. The expense has been roughly estimated at only $600. The alternative is to take one of the rooms on the lower floor, near the front door, but the cost would quickly overbalance the expense of the other more convenient arrangement.

The Library, with its numerous constantly arriving accessions to be thoroughly catalogued and arranged, and the large number of visitors to be waited upon, is sadly in need of better means for more complete service in other matters of pressing importance. For instance, if the Librarian had one more assistant, much time could with great advantage be occupied in following up

the acquisition of a vast number of municipal and governmental annual or serial publications of great engineering value, and also innumerable trade catalogues, that would be of great use if systematically arranged. Such publications could be obtained gratuitously, because it is clearly to the interest of those who issue them to have them placed where they would be properly cared for and made readily accessible to the public. But it is necessary to look constantly with watchful eye for their appearance, and occasionally to inform a new official or a new manufacturer of our desire for the publications, and there is, besides, the attention required for the cataloguing and convenient systematic arrangement. The present service of the Library is too short-handed to attend properly to this very important branch of our work. Setting the pamphlets in proper order, when new quarters are provided, will also require a great deal of unusual labor.

The binding is still so far in arrears, a liberal appropriation for the purpose is earnestly desired, in order that good progress may be made towards a satisfactory condition of the Library.

The main addition of books has been, as usual, from special gifts, and next from the volumes of serials received in exchange for the Journal.

The Moore Fund, ordinarily yielding about $750 a year, has, unfortunately, the past year, enabled the purchase of but few books. The Memorial Library Fund, about $50 a year, has supplied a better number of books than the preceding year. The Lea Fund, about $150 a year, has now fairly begun to bring in new books. The James T. Morris Fund of $2,000 has not yielded any income for the purchase of books.

The zeal and harmony of the Library Committee continue unabated, and it is believed that benefit will result from its meetings and earnest discussions, even if the temporary condition of the fund investments should occasionally make it impossible to order books to be purchased.

BENJ. SMITH LYMAN,
Chairman of the Library Committee.

PHILADELPHIA, January 7, 1901.

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1900.

GENTLEMEN:—The following summary of the work of the Committee on Science and the Arts for the year 1900 is respectfully submitted, showing that the large number of subjects presented for its consideration have received the usual careful attention expected, and have been passed upon impartially in accord with their merits. An unusual number of especially meritorious inventions have come to the Committee during the past year, due mainly to the references made of such subjects by the Board of Judges of the late National Export Exposition, in whose judgment such inventions were deserving of further recognition by the Franklin Institute, nearly all of which cases have been finally acted upon.

Very respectfully,
H. R. HEYL,
Chairman Committee on Science and the Arts.

PHILADELPHIA, January 2, 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1901.

STATISTICS OF THE OPERATIONS OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR 1900.

Cases pending December 31, 1899		35	
Applications received in 1900	27		
Cases referred by Institute	2		
Investigations ordered by Committee	5		
Investigations referred by Jury of Awards, National Export Exposition	31		
		65	
			100
Cases considered in 1900	58		
Cases finished in 1900		52	
Cases pending December 31, 1900		48	
			100
Reports pending same date			6
Awards of the Elliott Cresson Medal			6
Recommendations of the award of the John Scott Legacy Premium and Medal			12
Awards of Edward Longstreth medals of merit			12
Awards of certificates of merit			3
Reports made advisory			8
Cases withdrawn			2
Cases dismissed			8
Reports without awards			4
Protests			1
Cases pending December 31, 1900			48

ANNUAL REPORT OF THE COMMITTEE ON MEETINGS, 1900.

To the President and Members of the Institute:

The Committee on Meetings has arranged the program for the ten stated meetings of the Institute, with the Secretary's co-operation, and from the general interest exhibited by the members in these monthly gatherings the Committee may hope that its efforts to provide attractive material have been successful.

These arrangements have resulted in the presentation of twenty-three papers and miscellaneous communications, a number of which have found their way into publication, and others have been referred to the Committee on Science and the Arts.

The Committee has continued the publication of the Monthly Bulletin, which, although involving considerable cost, it is believed to be good policy to continue as heretofore. It should be said, in conclusion, that the growing activities of the Institute in the various sections are steadily making it more difficult for the Committee to maintain the greatest possible interest in the monthly meetings, but this circumstance the Committee believes to be rather

a subject for congratulation than the reverse, since it is the evidence of greater individual activity on the part of members in promoting the objects for which the Institute was organized.

Respectfully,

WASHINGTON JONES,
Chairman Committee on Meetings.

January 1, 1901.

ANNUAL REPORT OF THE CHEMICAL SECTION FOR THE YEAR ENDING DECEMBER 31, 1900.

The Committee on Sectional Arrangements:

The Chemical Section has held eight meetings during the past year, at which the following communications were presented and discussed:

Prof. S. F. Peckham. "What is Parianite?"

Prof. Edward L. Nichols, Cornell University. "Investigation of the Acetylene Flame."

Mr. B. H. Morrison. "Chemistry of Paper."

Dr. S. P. Sharples, Boston. "The Utilization of Animal Wastes."

Dr. S. P. Sadtler. "A Review of the Subject of Mineral Tanning."

Dr. Joseph W. Richards. "Report on the Aluminium Industry as shown at the Paris Exposition."

Dr. Richards. "The Utilization of Blast Furnace Gases in Gas Engines."

Dr. Henry Leffmann. "Methods of Micro-Chemical Analysis."

Mr. Charles J. Reed. "Electro-Chemical Action" (Joint Meeting with Electrical Section).

Several of these communications were published, with discussion thereon, in the Journal.

In the early part of the year, the Photographic and Microscopic Branch of the Section was, on the petition of its members, allowed to sever its connection with the Section and reorganize as an independent Section.

The meetings were as a rule well attended and the membership and general interest in the Section's work has been maintained.

By order of the Section.

W. J. WILLIAMS,
President.
W. E. RIDENOUR,
Secretary.

ANNUAL REPORT OF THE ELECTRICAL SECTION FOR THE YEAR 1900.

The Committee on Sectional Arrangements:

The Electrical Section has fully maintained its activity during the past year. Nine meetings were held, all of which were well attended, and of the papers presented, several were of considerable importance, as an inspection of the Journal in which they appear will testify.

Following is a list of authors and titles of communications presented during 1900:

Prof. John Price Jackson, State College, Pa. "Electrical Machinery in Coal Mining."

Prof. W. S. Franklin, Lehigh University. "Mechanical Conceptions of Electricity."

(Discussion) "Incandescent Lamps."

Mr. Adam Bosch, Newark, N. J. "Development of the Fire-Alarm Telegraph."

Mr. Chas. F. Scott, Westinghouse Electric and Manufacturing Company. "Modern Central Station Practice."

Mr. J. Franklin Stevens, Philadelphia. "Electrical Instruments."

Mr. C. H. Bedell, Philadelphia. "An Electrical Revolution Indicator."

Mr. Bedell. "The Pfatischer Electrical Steering Gear."

(Discussion) "The Electrical Distribution of Power in Workshops." (Joint meeting with the Mechanical and Engineering Section.)

Mr. Chas. J. Reed, Philadelphia. "Electro-Chemical Action." (Joint session with the Chemical Section.)

The outlook for the continued activity of the Electrical Section is most favorable.

Respectfully submitted,

W. S. FRANKLIN,
President.

RICHARD L. BINDER,
Secretary.

ANNUAL REPORT OF MINING AND METALLURGICAL SECTION FOR THE YEAR 1900.

The proceedings of the Section have been conducted by the following officers:

President, Mr. Joseph Richards.

Vice-Presidents, Mr. A. E. Outerbridge, Dr. David Tuttle.

Secretary, Mr. G. H. Clamer.

Conservator, Dr. Wm. H. Wahl.

Membership.—The total membership at the present date shows an increase of ten over the year 1899.

Meetings.—The Section held ten meetings during the year.

Work of Section.—The papers which were presented at the various meetings were all of decided interest, as was also the discussion of Mr. Paul Kreuzpointner's paper, "Riddles Wrought in Iron and Steel." This discussion was made the subject of several meetings, and has added much to the valuable work of the Section.

The following papers were presented:

Prof. F. Lynwood Garrison. "Lead and Zinc Mines of Southwestern Missouri."

Dr. David T. Day. "Modern Uses of Fuller's Earth."

Mr. Wm. Griffith. "Flushing of Culm into Anthracite Coal Mines."

Prof. John Gifford. "Forestry in Europe and America."

Mr. Paul Kreuzpointner, Mr. A. E. Outerbridge, Mr. Wm. R. Webster. (Discussion of Mr. Kreuzpointner's Paper) "Riddles Wrought in Iron and Steel."

Mr. Robert Job. "Some Causes of Excessive Heating in Bearing Metals."

Mr. Joseph A. Steinmetz. "Practical Application of Aluminum."

Prof. F. Lynwood Garrison. "Mines and Minerals of China."

Mr. Chas. Morris. "Subterranean Waters."

JOSEPH RICHARDS,
President.
G. H. CLAMER,
Secretary.

PHILADELPHIA, January, 9, 1901.

ANNUAL REPORT OF THE MECHANICAL AND ENGINEERING SECTION FOR 1900.

Committee on Sectional Arrangements :

During the past year the Mechanical and Engineering Section held seven meetings, several of which were largely attended. The policy has been adhered to in the main, of devoting the meetings to the discussion of subjects of live engineering and mechanical interest.

The following subjects were discussed :

"Portable Machine Tools."

"Power Transmission by Belting, Ropes and Chains."

"Expanded Metal ; with Especial Reference to Reinforced Concrete Construction" (paper by James S. Merritt).

"The Economical Operation and Maintenance of Steam Boilers, and

"Electric Transmission of Power in Workshops."

The last-named theme was discussed in joint session with the Electrical Section.

Several of these subjects found place in the Journal.

The general interest of the members in the work of the Section continues unabated, and the officers are pleased to be able to report a favorable outlook for the coming year.

Respectfully submitted,

JOHN F. ROWLAND, JR.,
President.
DANIEL EPPELSHEIMER, JR.,
Secretary.

PHILADELPHIA, January 10, 1901.

ANNUAL REPORT OF THE SECTION OF PHOTOGRAPHY AND MICROSCOPY FOR THE YEAR 1900.

The following is a summary of the work of the Section during 1900, including the period in which the Section was carried on as a branch of the Chemical Section :

January 2d.—A new method of entitling lantern slides. John G. Baker. "Micro-Photography and Photo-Micrography," with illustrations by several members.

February 6th.—"The Applications of Photography and Microscopy to Medico-Legal Work." At this meeting the Section had the honor of com-

munications from two experts. Dr. W. M. L. Coplin gave an illustrated lecture, dealing principally with the recognition of blood stains, and Dr. A. W. Goodspeed exhibited a number of slides relating to X-ray work and also showed some pictures made with radiant substances.

March 6th.—"Apparatus for Testing the Speed of Camera Shutters." John G. Baker. "Remarks on the Chemistry of Development." Dr. Henry Leffmann.

April 3d.—"Development of Lantern Slides." S. Ashton Hand. Mr. Hand's collection of slides was a striking example of the value of a combination of science and technic in securing true and artistic results in photography.

"Picture-Making in the Dark." Dr. M. I. Wilbert. Dr. Wilbert exhibited a large number of slides made from negatives taken without any exposure to light, and also showed some pictures made from very old plates.

May 3d.—"Notes on Sodium Gold Chloride." Lyman F. Kebler. This communication pointed out the difference in net weight in the different brands of the article in the market.

"Remarks on the Subject of Picture-Making in the Dark." Dr. Henry Leffmann.

October 4th.—"Photographic Sophistications." John Bartlett. This paper was of novel character and aroused much interest.

November 1st.—"Notes on the History and Applications of Motion Pictures." Communications were presented by several members. Some very old motion slides were shown. Mr. Ives exhibited the "kicking donkey" adapted from Muybridge's picture. Mr. Heyl showed some slides which had been used in 1870 at an exhibition under the auspices of the Institute. These slides were used to exhibit motion effects.

December 6th.—"The Microscopic Structure of the Rocks of the Philadelphia District." Theo. D. Rand. This was largely illustrated and was an interesting and valuable contribution to local petrology.

Respectfully submitted,

HENRY LEFFMANN,
President.

F. M. SAWYER,
Secretary.

PHILADELPHIA, January 3, 1901.

ANNUAL REPORT OF THE PHYSICAL SECTION FOR THE YEAR 1900.

The Committee on Sectional Arrangements:

The Physical Section labors under the disadvantage, as compared with the other Sections of the Institute, of having a much smaller membership from which to draw for material for its meetings, being compelled on this account to depend more than the others upon contributions from non-members. This will, in a large measure, explain the occasional omission of one of its meetings.

The following communications were presented during the year just past:

Prof. Jesse Pawling, Jr., "Trilinear Coördinates as Applied to a Particular Problem."

Professor Pawling, "On Magnetic Curves."

Dr. G. B. M. Zerr, "On Aberration."

Prof. E. L. Nichols, Ithaca, N. Y., "The Acetylene Flame."

Mr. H. M. Watts, "On the Past History and Present Prospects of State Weather Services."

Dr. M. G. Lloyd, "On Thermo-Magnetic Effects."

The Physical Section, in conjunction with the Photographic and Microscopic Section, prepared and issued a joint bulletin giving instructions to its own and other observers of the total eclipse of May 28, 1900. Also, steps were taken looking to the appointment of a special committee to confer with the several scientific and educational institutions of the State, with the view of establishing a Weather Service on the lines suggested by the Maryland State Weather Service.

To increase the interest of the general membership of the Institute in the Section, it was decided to endeavor to devote more attention, if practicable, to the subjects usually included under the name of Terrestrial Physics. Also, the name of the Section was changed, by authority of the Board of Managers, to "The Physical Section" of the Franklin Institute.

Respectfully submitted,

A. E. KENNELLY,
President.

EDW. A. PARTRIDGE,
Secretary.

PHILADELPHIA, January 1, 1901.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, January 2, 1901.*]

MR. H. R. HEYL in the chair.

The following reports were adopted:

(No. 1992.) *System of Oil Heating and Incandescent Lighting.* Arthur Kitson, Philadelphia. Reserved for publication in full.

(No. 2124.) *Forged Steel Car and Locomotive Wheel.* Facer Forged Car and Locomotive Wheel Company, Philadelphia.

ABSTRACT.—This invention is the subject of letters-patent of the United States, No. 564,603, July 28, 1896, granted to applicant.

From an examination of the means described for producing this wheel, it appears that the arrangement of the top die is the same as that usually employed in the manufacture of tires. The difference between this and existing methods consists in the wheel being held in a V-shaped die in the former process, whereas the tires are held on the horn of the anvil in the latter. The sub-committee examined the subject from the standpoint (1) of novelty of the method; (2) excellence of workmanship; and (3) quality of product. As the result, the conclusion is reached that the applicant has not demonstrated that a marketable wheel can be made by the process, and that, in the absence of such proof, it was not considered necessary to enter into the consideration of the question of novelty. [*Sub-Committee.*—Thos. P. Conard, Chairman; H. V. Wille, J. Y. McConnell, A. E. Outerbridge, Jr., A. A. Stevenson, W. B. Riegner.]

(No. 2145.) *Method of Compressing Air by Means of Water.*

(No. 2146.) *Method of Raising Water by Compressed Air.*

Abstract.—These inventions are the subject of U. S. letters-patent No. 199,819, January 29, 1878, and No. 233,499, October 19, 1880, respectively, granted to applicant, J. P. Frizell, Boston, Mass.

The first relates to a method of compressing air by means of the entrainment of air in minute bubbles by a stream of water. The water is carried vertically downwards within a pipe and the entrained air is liberated at any desired depth in a horizontal passage, the pressure corresponding to the height of the water column.

The investigating committee finds this principle of operation to be identical with that used in the apparatus known as the "trompe," an ancient device used in the Catalan forge. The investigators, moreover, consider the plan of applicant, of liberating the air in a horizontal passage, to be rather a step backwards. The method of Taylor (exhibited in the plant of the Dominion Cotton Mills, Magog, Canada), of liberating the air in a box, corresponds more closely to the form of the old trompe and, in their judgment, is simpler.

The second invention consists in a method for the aëration of a water column by the introduction of air in minute bubbles, thus reducing the specific gravity of the mixed fluids in the pipe, below that of the surrounding water. The mixed air and water consequently will rise to a considerable height above the water level. In the procedure known as the "Pohle Air Lift" (which is referred to by applicant as a substantial appropriation of his invention) the air is introduced in large volumes into a column of water, thus differing from the procedure of applicant. Furthermore, the Pohle method involves, not only the mixture of air and water and the utilization of the elasticity of the air which expands as the mixed fluid approaches the discharge outlet—which operations are embodied in the plan of applicant—but also adds the use of the inertia of the injected air as the pipe introducing the air into the water column is turned upwards in the direction of the stream, whereas in applicant's apparatus the air is introduced in a direction at right angles to the stream.

In the committee's opinion, all the principles involved in applicant's as well as Pohle's inventions are not new, being applied more or less completely in numerous forms of the devices known as ejectors. The conclusion is reached that applicant has not made any marked step in advance in his several inventions. [*Sub-Committee.*—A. Falkenau, Chairman; S. Howard Rippley, Arthur M. Greene, Jr., Wm. Copeland Furber, John E. Codman.]

SECTIONS.

(*Abstracts of Proceedings.*)

Section of Photography and Microscopy.—*Stated Meeting*, held Thursday, January 3, 1901. Dr. Henry Leffmann in the chair. Present, 32 members and visitors.

The annual election for officers resulted as follows: President, Dr. Charles

F. Himes; Vice-Presidents, F. E. Ives, John G. Baker; Secretary, Frank M. Sawyer; Conservator, Dr. Wahl.

The communication of the evening was the address of Dr. Leffmann, the retiring President, who spoke on "The Applications of Photography to Police and Sanitary Administration." The speaker's remarks were freely illustrated by means of lantern slides, which served to demonstrate very strikingly the great importance of the photographic art in the numerous varied fields covered by this work. The paper is reserved for publication.

F. M. SAWYER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, January 9, 1901. Mr. Joseph Richards, President, in the chair. Present, 18 members and visitors.

The annual election for officers resulted in the choice of the following: For President, Prof. F. L. Garrison; Vice-Presidents, James Christie, Joseph Richards; Secretary, G. H. Clamer; Conservator, Dr. Wahl.

The retiring President conducted his successor to the chair.

The paper of the evening was the address of the retiring President, Mr. Joseph Richards, who chose as his subject, "The Utilization of the Wastes from the White Metals." Only one branch of this interesting theme was considered at this meeting, namely, the Utilization of Galvanizers' Wastes.

The speaker illustrated the subject by means of an instructive collection of specimens of the various kinds of those wastes which were commercially utilized, and of the several qualities of refined metal obtained by various processes employed. Referred for publication.

The thanks of the meeting were voted to the retiring officer. By special request, the subject will be continued at the next stated meeting.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, January 10th. Mr. John F. Rowland, Jr., in the chair.

The evening was devoted to the presentation of an address on "Wear and Tear on Steam Boilers" by the retiring President, Mr. Rowland. The subject was afterwards discussed.

The annual election of officers was deferred until the next stated meeting.

DANIEL EPPELSHEIMER, JR.,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, January 17th. Vice-President Joseph Richards in the chair. Present, 23 members and visitors.

The following officers were elected to serve for the current year, viz.: President, Morris E. Leeds; Vice-Presidents, Joseph Richards, Geo. T. Eyanson; Secretary, Richard T. Binder.

There were presented two communications, both of which were freely discussed, viz.: "A New Departure in Constant-potential Arc Lamps," by Thomas Spencer, and "Three-phase Electric Traction in Europe," by Mr. Carl Hering.

RICHARD T. BINDER,
Secretary.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLI, No. 3. 76TH YEAR. MARCH, 1901

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, December 19, 1900.

A DISCUSSION OF RECENT DEVELOPMENTS IN THE FIREPROOFING OF WOOD.

BY JOSEPH L. FERRELL, M.E.

I have the honor to present in this paper a simple statement of ascertained facts, susceptible of easy and prompt verification, and offer no theories whatever in the subject under consideration.

Whether it is valuable to render wood an obstacle to flame, rather than a contributor to it, can hardly be considered as a serious proposition; evidence as to the practical doing of the thing is here before us.

The methods of doing it, the tools with which it is done, the efficacy of treatment, are the subjects of this paper.

Up to seven years ago the history of this art was a series of sporadic attempts to impregnate boards and timbers by

impracticable processes and apparatus, with impossible chemical solutions; and the best evidence of their worthlessness is their failure.

In the United States Patent Office over 400 patents have been issued since 1790. These are all chiefly interesting from the impossibility, inherent in their nature, of practical operation.

Much ingenuity had been shown in devising apparatus and processes for the impregnation of wood with preservative substances, and the best form of such apparatus has recently been adopted by those who have made the commercial initiative in fireproofing wood. In fact, the actual apparatus, identical in almost every feature, used by the first company to fireproof wood for private and governmental uses, was for some time used to treat wood with preservative solutions.

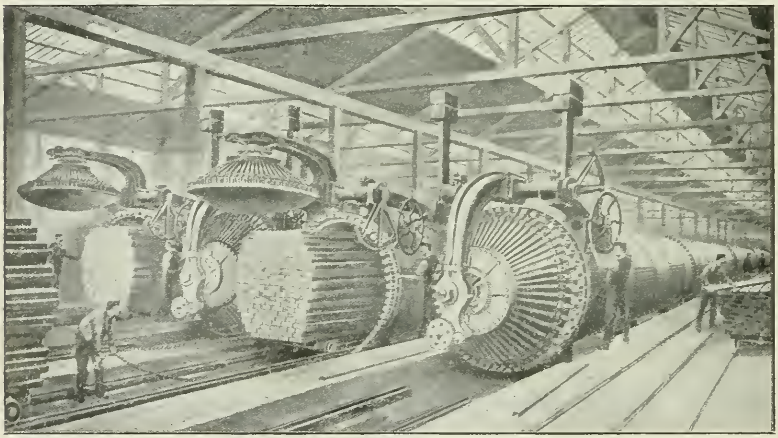


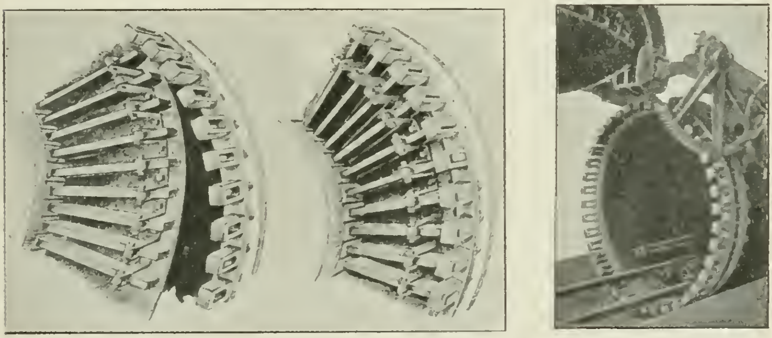
FIG. 1.—Old type of cylinder, showing complicated and cumbersome external end-gate.

The old apparatus is in general similar to that shown in accompanying engraving. It consists of a cylinder of about 84 inches diameter, built up of steel or iron plate, in some cases 100 feet long, with a door at the front end swung upon hinges and fastened with a multilocking system of bolts. On the bottom of the cylinder is a track upon which

the cars loaded with lumber rest. The cars are run in through this door, and when the treatment is over are backed out again and sent to the dry-kiln.

To saturate wood the lumber is placed in the cylinder, the door closed and fastened, steam is admitted, and the wood subjected for hours to its action. The purpose claimed is the softening of the mass and the saps contained therein.

This operation is followed by a vacuum which aims to extract the liquefied saps, so far as practicable, and this process also occupies many hours. Subsequently the vaporized mineral salt was admitted to the softened wood (this part of the process is now discontinued), and finally the



FIGS. 2 and 3.—Details of old type end-gate.

liquor was run into the cylinder, completely filling it, after which a powerful pressure pump was set in motion and pumped additional liquor into the cylinder, thereby raising the pressure therein.

This operation also occupied a long time, the whole series of operations requiring from 20 to 35 hours, according to the kind and thickness of the wood under treatment.

As the first movement to achieve a practical result, this was a very creditable one. As a complete, practical and logical system, it proved a complete failure.

The old systems are based upon fallacies:

(1) Steam in contact with all woods destroys the fiber, and seriously affects its color.

(2) In so far as steam does soften the wood, so does the subsequent vacuum act upon the softened fiber and seriously distorts it.

(3) The most serious result is the loss of the liquefied saps and substances contained in the wood, which are as valuable to the wood, as wood, as the fiber itself, and if it were possible for the vacuum actually to suck out all the liquefied saps, the remaining fiber would have no cohesion and would be a friable, spongy mass of useless material.

The fact that the vacuum can only get at the saps of the surfaces or near to the surfaces is the salvation of the wood treated in this way, and, in a great measure, the objection in the case of decks of ships and other places where the surfaces of wood thus treated are exposed to wear, that it roughens up and rubs off, is due to the fact that the cohesion of fiber is disturbed, and that there is no natural substance left with which, at least in a degree, the impregnating chemical may unite in forming a new insoluble substance in the superficial wood cells, consequently the chemical lies in crevices instead of being incorporated with the fiber, and readily washes out and is displaced.

Referring to a report made by experts of the U. S. Navy Department as to fireproofed woods submitted by the two companies now in operation, which report is dated November 27, 1900, the following passage occurs: "The tests have already progressed sufficiently to show that the ultimate values of the woods treated by the two processes are very nearly equal, yet in both the products are imperfect in that they do not remain permanently impregnated with their fireproofing compounds under certain circumstances encountered on navy vessels."

It is difficult to understand how this loss can occur, if the compounds are the phosphates and sulphates of ammonia, except for the reasons before alluded to, that the treatment measurably evolves the albuminous substances and other sap products from the surfaces and layers near the surfaces, thus obviating any practical chemical union around the individual fibers.

Henry Valentine Simpson, Lieutenant R. N. (England),

who for a long time managed the practical part of the business for the London Non-Flammable Wood Company, Limited, of London, England, writes under date December 5, 1900: "Our climate is certainly against this process; the wood sweats in damp weather, drawing the salts to the surface. I am certainly deeply interested in this industry practically * * * * and, next to yourself, believe I know as much about it as any one."

Lieutenant Simpson has patented other chemical solutions, which he believes will achieve the location of an insoluble product in the wood. From his acute intelligence and from his long practical familiarity with the old operative machines, he is to-day probably the best trained expert in the world working on the old lines of apparatus and processes. It seems now to be an established fact that successfully fireproofed wood must have the chemical fixed in the wood immutably, so that no atmospheric or other effects can possibly disturb it.

Investigators are gradually coming to a definite agreement on this point, and the general subject is attracting the most serious attention of disinterested scientists all over the world.

The *Journal of the Society of Chemical Industry* (London) contains, in its issue of December 30, 1899, a paper presented by Sherard Cowper-Coles, which, with the record of the accompanying discussion by eminent members of the society, affords a clear view of the situation as regards the then known status of the art.

"A number of tests by Drude tend to prove that steaming wood before impregnating tends to lessen its absorptive powers. Simpson has found that oak, if exposed long to the action of steam at a high temperature, is very apt to warp or crack; soft woods, such as deal, pine, ash and the like, are apt to become discolored under the same conditions.

"Dr. O. J. Steinhart, of the Society, in course of the discussion, asked whether phosphate of ammonia was the fireproofing material employed by Simpson. He stated that phosphate of ammonia gave rise to a fungoid growth which might rot wood. He also would like to know what was the

corrosive action of phosphate of ammonia on metallic parts. He considered that important, as, if phosphate of ammonia were used, iron parts might come into contact with the impregnated wood in ships, etc. He had always understood that phosphate of ammonia did affect ironwork.

"Mr. Sayer said that woods impregnated with salts of ammonia were unsatisfactory."

These are the judgments of acute observers, which confirm the results of practical commercial tests.

After all, there is no method of arriving at final and conclusive results so perfect as by the patient development of simple apparatus for impregnation, which will do the plain work beneficently and rapidly on the large practical scale, and (knowing by long experience, and experience only, the injurious effects of the old chemical formulæ) to devise new formulæ free from the detrimental qualities complained of by those who have used the products already given to the public.

The chemical problem is now the most serious one, not wholly because of the great difficulty in laying hold of a formula which will respond to the requirements for use, but in getting a formula the cost of which shall be no obstacle to making the fireproofing of wood of universal applicability.

The apparatus which will thoroughly saturate wood with preservative solutions will, of course, equally perform the function of saturation with fireproofing solution.

The old forms have become obsolete, because a more complete, practical study has disclosed their errors and weak points, and their superfluous complications, all of which means cost and expensive operation.

Development in this direction proceeds logically and from inherent necessity, just as in every other phase of human progress. Take the form of pumping engines of only half a century ago and compare them with those in common use to-day!

The subject of saturation is as yet scarcely touched. If what we are doing affords promise of universal application because of the good results obtained, and wood can be preserved and fireproofed cheaply and beneficently, a new

industry will surely be created, of vast proportions. Chemical science may reasonably be expected to develop ingenious, cheap and thoroughly efficacious formulæ; whence it may come to pass that wood will be made immune from fire and decay at a merely nominal cost. All we expect to accomplish is to advance the art a step.

It is not easy to understand how the mechanical features of saturation can be more simplified than in the new cylinder machine. The operation is so effective and direct that, were it not for the subsequent drying, boards and thin planks could almost be saturated with the chemical whilst the lumber wagons waited for them, instead of occupying days for the cumbrous and complicated old system to perform the same function. The elimination of the useless and very injurious preliminary processes of long steaming and subsequent suction means an enormous saving of time, and avoidance of harm to the wood under treatment.

It must be considered, however, that, independently of the objects claimed for the steaming and vacuum, a decided advantage accrues to the users of this process, in that the wood is rendered open and soft, so that a comparatively light pressure on the liquor in the cylinder, in the last operation, suffices to penetrate, where it would not otherwise reach.

Now, the pressures employed must necessarily be light for two reasons:

(1) The cylinder itself will not endure a heavy pressure, nor will the gate, being exteriorly attached, keep tight; and, when leakage occurs, pressure drops.

(2) The pressure, being applied directly by a pressure pump, must be deftly manipulated to prevent the water-hammer from utterly destroying the softened fiber; therefore, for this reason rapid operation or high pressure is out of the question. The saturation, therefore, by this process must occupy a seriously long time, and the wood must necessarily suffer more or less injury. The pressures being light renders it impossible to saturate to the heart any dense wood, or any great thicknesses of soft or light wood. The great length of time is absolutely prohibitive of cheap

treatment. The enormous cost of the principal and least objectionable chemical also bars the way.

Pure phosphate of ammonia, which can be bought at the present time for 9 cents per pound, means for a 130 per cent. saturation of white pine, with a 20° Beaumé solution, a cost of $71.79 per thousand feet for the chemical alone, although, after exhaustive investigation, we believe it can be manufactured in this country for about 5 cents per pound, in which case the cost of the chemical would be $39.89 per thousand feet. Therefore, to do business a resort must be had to a cheaper element, which has distinct and serious disadvantages. Even at the best, by the use of other chemicals, the cost of chemical alone ranges about $25 per thousand.

Of course this is all impossible. Unless the wood can be treated rapidly and beneficently with a cheap chemical without a single detrimental quality, and on the whole strengthened and bettered in other ways than the fireproofing, fireproof wood cannot reach the public.

To accomplish this result, years of unremitting labor have been applied. Instead of the old haphazard, empirical methods, a clearly defined, scientific study has been followed along scientific lines.

First, taking the art in the phases known, examinations were made of the most thorough character into the nature of all the principal commercial woods, and the methods previously employed were reproduced in long series of tests, to ascertain effects of the different elements of the old processes, and their respective values.

The results of these tests proved conclusively that—

(1) Steaming is radically wrong in principle.

(2) Suction is in the highest degree injurious.

(3) Direct application of reciprocating pressure, especially to wood subjected previously to the above treatment, is destructive.

These determinations, therefore, compelled the abandonment of the mechanical features and processes of application which had previously been employed.

Granting, however, that the old mechanical methods and

processes were beneficent and scientific, and that the wood could be uniformly and perfectly saturated with a chemical absolutely unexceptionable for the effects intended, it yet remains a fact that the *time factor* alone would render the whole system impracticable for universal use. On this point, it is sufficient to say that the old method demands from twenty-five to thirty-five hours to produce requisite saturation of thin sections of wood.

If, added to this impracticable feature, we have a chemical solution, the best by general consent then discovered, costing at the very least $25 per thousand feet board mea-

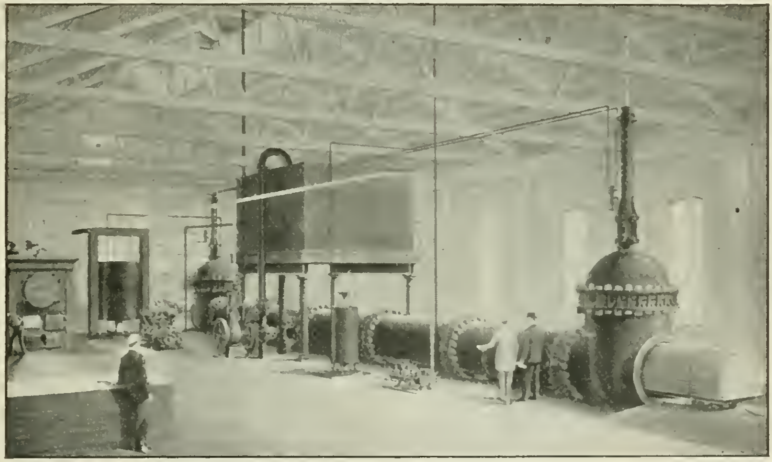


FIG. 4.—Cylinder used in new process, showing internally seated end-gate.

sure, the impossibility of any practical solution of the problem must be obvious at a glance. For, no matter how perfect the fireproofing effect, how permanent, how beneficent to the wood treated, if the total cost is excessive, it becomes prohibitive.

It became necessary to revolutionize the entire treatment of the subject.

Instead of the application of low pressures and long time, the employment of high pressures and short time of saturation was tried.

Steaming was at once discarded; vacuum also.

The wood, therefore, being in its normal condition, was treated directly with the solution under pressures from 50 to 1,200 pounds, and results carefully noted.

Every thickness up to 10 inches square, of sixteen different kinds of wood, was thus treated, and treated each in long series.

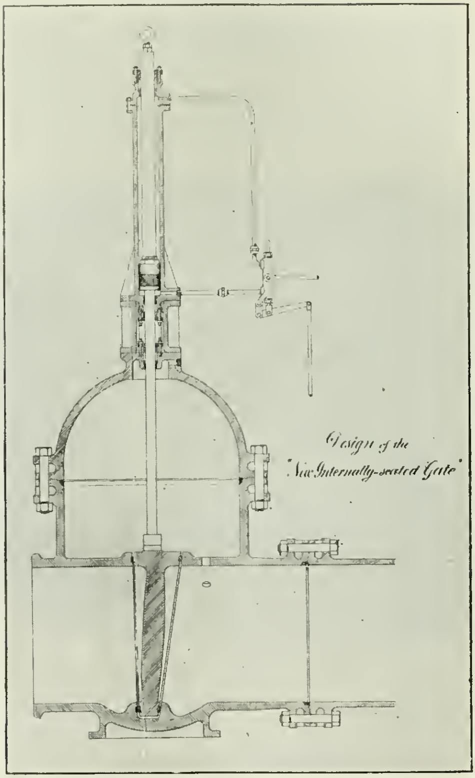


FIG. 5.—Details of new internal end-gate.

It was discovered that each thickness of each wood had its exponent of resistance to compression, but the greater pressures were apt to overcompress and distort the wood. To obviate this, the hydraulic accumulator was interposed, which at once and most satisfactorily obviated all welting and distorting, and by the maintaining uniformity of pressure, instead of reciprocating application, produced much more rapid saturation.

All this preliminary study was done with a small apparatus, and it became necessary, for practical purposes, to know what could be done in an apparatus of commercial size.

At once the problem arose as to the type of gate for the cylinder. The old forms, as a matter of course, could not endure the enormous pressures it became necessary to use in working out this principle, nor could the old plate cylinders of large commercial size endure such pressures.

Therefore, steel castings were adopted for cylinders, competent, in the first small commercial test plant, to stand a pressure of 1,500 pounds to the square inch, and the gate devised was an internal disc, rising vertically, lifted by accumulator pressure, seated outwardly and pressed to the seat by the pressure of saturation.

A cylinder 12 feet long was therefore made, 18 inches diameter, attached to a massive gate body. In this cylinder, for twenty months, every size of every commercial wood has been rigorously tested and the result most carefully tabulated.

White pine boards, under a pressure of 300 pounds per square inch, are saturated to from 120 to 140 per cent. in half an hour, as against about 90 per cent. by the old system in thirty hours.

The problem of healthful saturation of all woods by high pressures by external compressional applications is finally and correctly determined.

Concurrently with the mechanical studies ran of necessity the chemical study. Its importance is vital, as it is the most serious element in the whole matter.

Wood, at the beginning of this investigation, had never been known to the world to be perfectly saturated to an ample degree with any solution, which was wholly harmless to the wood, to produce immunity from flame.

This is a broad general statement, and of course is only meant to affirm that such was the case as to general knowledge.

The Russian chemist, Peter Lochtin, who made a most crucial investigation into this subject some years since, tested nearly a hundred substances and finally sifted them

FIG. 6.—Before applying the torch. Test of fireproofed wood made at the yards of the New York Shipbuilding Co., Camden, N. J., June 19, 1900. Two small buildings were erected similarly constructed, one built of ordinary wood and the other of wood fireproofed by the Ferrell process.

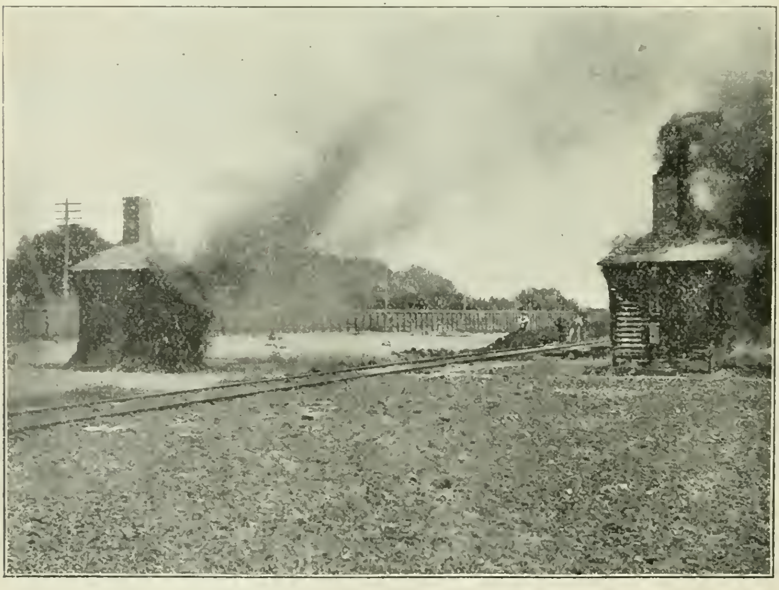


FIG. 7.—After burning eight minutes.

all down to a possible three or four, first among which was phosphate of ammonia, and second, sulphate of ammonia. He gives the relative values of all the others and the reasons why they do not respond to the final tests of utility.

Phosphate of ammonia, of all substances known at the beginning of this investigation, was the most promising. Wood, perfectly saturated with it to the heart, resisted the fiercest flame more effectively than any other solution, but its cost is prohibitive. In a pound of the chemical, the cost of the ammonia requisite is alone beyond the cost permissible of a pound of the chemical which can be used for this purpose, and make it a practicable thing, leaving out the cost of the necessary sulphuric acid, however produced, with the other accessory costs of production.

Even were it cheap enough to be used, work enough has been done to determine beyond question that, whilst it is the least harmless to the wood of all the long line of solutions, it still does have an effect to render the fiber brittle, and this seems impossible to counteract.

Sulphate of ammonia comes next in value, a stronger solution, however, being necessary to produce an equal fireproofing result.

But the difficulties of the phosphate are accentuated in the sulphate. Wood loses its brightness of color, its flexibility of fiber, and it shows a more hygroscopic tendency.

Both the phosphate and sulphate corrode metals. The sulphate, from its relative cheapness, and from its excellence of fireproofing, is a most attractive chemical, and therefore is more used than anything else. This corrosive action has been the cause of the complaints of the English Government as to the work done by the London Company on the Queen's yacht and several vessels of the Admiralty, and for the United States Government on many vessels of war, which have been the subject of much unfavorable criticism, and have dampened the interest of the public generally in the subject of fireproof wood.

Where these chemicals are used separately or in combination the results complained of will infallibly occur. Even if the sulphate of ammonia could be rendered harmless, it

FIG. 8.—After burning fourteen minutes.

FIG. 9.—After burning sixteen minutes. House built of ordinary wood completely destroyed.

could only be done at an addition to its present cost of 3 cents per pound, and that cost alone is prohibitive to its broad use. Therefore it has been compulsory to traverse a wholly new ground, not even trodden by the distinguished Russian chemist.

Years of incessant and laborious practical investigation have been devoted to this side of the question, and the result has been a marked advance upon the previous history of the chemical side of the fireproofing question.

Two formulæ have been discovered and tested finally as to their perfectness for this use. By their employment the chemical cost will be reduced to less than one-third of what it has ever before been, and when the wood is saturated with the solution, it is wholly free from the faults hitherto complained of.

It maintains its original color and freshness. It will not corrode metals in contact. It will not attract moisture. It will not brittleize the fiber. It will never volatilize by time. It will take paint and varnish and retain them.

This chemical result, with its perfection and low cost, combined with the low cost and short time of mechanical treatment, makes the universal use of fireproofed wood quite practicable.

In treating sawn lumber in the liquid bath, each kind of lumber and each thickness of that kind has its own peculiar coëfficient of normal pressure at which it will become impregnated with the greatest rapidity.

If we exceed this, the pressure compacts the fibrous mass, and prevents the rapid saturation, filling the superficial layers with an excess of solution and preventing the proper amount from reaching the heart. Thus, it may happen that, there is a great excess of the chemical, when dried, over what is necessary to perform effectually the functions of fireproofing the whole mass; yet a half inch under the surface the solution has not penetrated. This cannot occur if the ascertained conditions of saturation are obeyed, by which an even distribution of the solution is located throughout the mass. In larger sections, say from 6 inches by 8 inches and upwards, and particularly in the denser woods, this is more likely to occur.

The long time, relatively, it required to treat all larger sections in the correct way, that is, evenly throughout, to the heart, suggested a new departure in investigation, which has been successfully carried out in a marked degree.

This development may be termed the expressive, in contradistinction with the other, which we will call the compressive treatment.

In one sense the expressive idea is not new, any more than the compressive, only the means employed and the employment of the means radically vary from anything which can be found on record, after long and exhaustive search.

One apparatus has been doing practical work on saturation of logs, running from 14 inches diameter up to 27 inches diameter, and 9 feet long. The apparatus is open, and the pressures of liquid are applied to the end centers. It makes no difference whether the logs or timbers are small or large in section or diameter, or of what length.

This machine necessarily must be constructed in three different forms to meet the peculiar conditions encountered in practice from varying structure of trees.

It is not practicable as yet to give the minute details of this process and apparatus, inasmuch as the patents are not sufficiently advanced to enable it to be done, but it is entirely true that timbers and logs of all commercial woods have been saturated in an incredibly short time, from center to periphery, every fiber having been enveloped in the saturating solution.

For instance, the section of holly log before us was part of a log averaging 17 inches diameter and 9 feet long. Of course it is known how dense a wood holly is. A holly log like this could not be equally saturated in the compressive system in the cylinder in a month, perhaps never, the wood being so dense and the necessary pressure in that system being so great, constriction of the fibrous mass would be so powerful that nothing but superficial saturation could take place.

In all great centers of population, where structural work is done on enormous scale, the buildings are supplied with

dimension lumber by the lumber yards. This is the source of supply from which all the boards, planks and small timbers will come to be fireproofed, when the necessity for that to be done is fully recognized, and when it is as thoroughly understood that fireproofing wood is an honest, every-day matter of business, and it can be done uniformly at a very low cost.

The internal compressive system of apparatus will do the work perfectly, quickly and cheaply on all woods up to 6 x 8 inches and on soft woods up to 12 x 12 inches. Above these dimensions, to any section or any length, the expressive apparatus will thoroughly operate at no greater cost per thousand feet board measure than is required to treat 1-inch boards by the other system. No matter whether the wood be white or yellow pine, oak, ash, poplar, beech, birch or any wood cut from a tree, it acts equally well and equally cheaply.

It will thus be seen that the apparatus termed the expressive is the supplement of the internal compressive type; and both together comprise a system of practical operative machines which effectively covers the whole ground of saturation.

The invitation so kindly tendered by the Institute to present the actual facts as to these discoveries is most heartily welcomed.

That the matter is interesting to the professional minds of this body is a source of the sincerest gratification.

THE PARIS EXPOSITION, 1900.

SOME NOTABLE ELECTRICAL ITEMS.

BY DR. A. E. KENNELLY,
Delegate of the Institute.

The International Electrical Congress of 1900 at Paris was well attended. Seven hundred and sixty members were enrolled, and eighty-three official delegates from the various governments. The congress met on the 18th of August, at Congress Hall, in the exposition grounds, and held its later

sessions (closing the 25th of August) at 44 Rue de Rennes. A number of interesting papers were read. The congress adopted names for two electro-magnetic units in the centimeter-gram-second electro-magnetic system; namely, the "maxwell" as the C.G.S. unit of magnetic flux, corresponding to what has frequently been called a "line" in the past; and the "gauss" as the C.G.S. unit of magnetic intensity, or flux density, corresponding to one maxwell per normal square centimeter.

Among practical electrical features of the exposition, one of the most interesting and successful was the moving sidewalk, which formed an endless belt within the interior contour of the exposition lines of buildings. It had a length of 3,400 meters. It consisted of one stationary platform 1·6 meters wide, next to it a moving platform 0·90 meter wide, travelling at about 2½ miles per hour, and next beyond this a moving platform 2 meters wide travelling at double speed or about 5 miles per hour. All three platforms were situated at an elevation of about 7 meters above the ground. The moving sidewalks were driven by 172 5 horse-power direct-current 500-volt series iron-clad motors. The motors were intended to be operated in parallel, but sufficient speed was obtained when they were connected in parallel arrangement of two in series. The weight of the high-speed platform was about 1,000 metric tons, and of the small platform 700 metric tons, making the total weight moved 1,700 metric tons, without passengers. As many as 15,000 persons are estimated to have been carried at one time on the platform. The motors were uniformly distributed along the route and were stationary, one side being mounted on a fixed axis and the other pressed upward by a spring so as to engage the motor pulley with the lower surface of an I-beam in the base of each platform. The motors seem to have operated with entire satisfaction throughout. The starting direct current supplied to the motors was about three times the current required for their normal operation. About 230 kilowatts is stated to have been expended at the sub-station generator for the operation of this platform when empty, and this increased

to about 330 kilowatts at maximum load, or about 260 kilowatts under ordinary normal load. The sidewalk was usually in operation between the hours of 10 A.M. and 7 P.M. The direct current was generated by a 600-kilowatt Westinghouse generator coupled directly to an 850 horse-power multiphase induction motor supplied through transformers from 5,000-volt mains leading to the power house at Issy-le-Moulineaux.

The sidewalk was very popular and effective. It has shown that where sufficient space can be obtained, large crowds can be successfully carried at low speeds to a limited distance at a low expenditure of power per individual. On the other hand, however, the method would be very wasteful and costly where only a small number of persons has to be carried. No seats were provided on the platform, and beyond the fencing, the only objects rising above the platform levels were vertical wooden posts about 3 feet 6 inches high, terminating above in a wooden knob to aid persons in passing from one platform to another.

Mining and Metallurgical Section.

Stated Meeting held Wednesday, December 12, 1900.

TALLOW CAVE, NORTH DORSET, VT., AND MARBLE NATURAL BRIDGE, NORTH ADAMS, MASS.

By Edwin Swift Balch, Member of the Institute.

Tallow Cave is situated on Dorset Mountain, southwest from North Dorset, Vt. It is about fifty minutes' walk distant from the railroad station, up a rather steep and rough mountain road. I visited it with my brother and one of the natives of North Dorset, on September 25, 1900. There is a sort of ravine with a little bluff at the top ; under this is the cave. The entrance is low and narrow, just large enough to pass through easily, and the wall of the cave goes down

steeply for about 5 meters from the entrance. On this wall we found, fortunately, a rough ladder of two birch poles, with twelve rungs. At the bottom of the wall is a chamber some 4 meters wide and 6 or 7 meters long, which turns to the right and narrows towards the end. Here there is a pit some 4 meters deep, which forms a second and lower chamber, into which we could not descend, as there was no ladder; by throwing down some burning birchbark, however, we could see that it was small.

The noteworthy feature about Tallow Cave is the mineralogical formation from which it obtains its name. The rock is a coarse white marble, which, at the entrance, seems as hard as other marble. Inside, 4 or 5 meters from the entrance, the walls, the roof and the floor might almost be described as soft. They are formed of, or covered with, a sticky, compact, whitish substance, not unlike putty in its consistency, and which can be cut out in lumps with a penknife. It certainly resembles tallow, only it is more solid. There are neither stalactites nor stalagmites within the cave, and, judging from my one visit, the temperatures are normal and there is no very abnormal excess of moisture. Mr. Thomas H. Garrett, the analytical chemist, and Dr. William H. Wahl have kindly analyzed samples of the "tallow" for me, and they report that it is carbonate of lime. It is, in any case, a rare formation, for I have visited perhaps a hundred caves and never seen anything like it.

I find, however, in M. Martel's recent book, "La Spéléologie," that a similar or, perhaps, identical substance has been found in three caves in Europe, and that it is called *mondmilch* (moon-milk), a name given by the Swiss peasants near Mount Pilatus, where it was first discovered. These European caves, however, are of ordinary limestone, while Tallow Cave is of marble, so that the "tallow" there is at any rate unusual. The explanation given by M. Martel is that *mondmilch* is carbonate of lime so thoroughly saturated with water that it cannot harden into stalactite.

Not far from Tallow Cave a deep sink hole called Purgatory is reported. After a careful and fatiguing search

through the dense forest, I am sorry to say that we were unable to locate it, although our guide professed to know the mountain. It is described as a funnel-shaped pit, in whose base is a vertical hole of unknown depth; and when big stones are thrown in they can be heard falling for several seconds. It must be a regular *aven*, as these pits are called in the limestone regions of Southern France. I have no doubt of the existence of this Purgatory, for we discovered

Natural bridge of marble, North Adams, Mass.

on Dorset Mountain two small holes which went down vertically out of sight, and also a large pit, perhaps 6 meters in length by 4 in width and 5 in depth, whose sides are nearly sheer.

In the town limits of North Adams, Mass., is a remarkable natural bridge, which I visited last October. It is close by the Beaver quarry, whose marble is used in the manufacture of soda water. The bridge spans a little winding canyon, which has been cut out by water and

whose marble edges are rounded off, forming hollows and basins such as one sometimes sees in mountain streams. The bridge is of marble, and is about 4 meters long, 3 meters broad and some 3 meters thick. The canyon under it is 4 or 5 meters deep. Both in formation and appearance the bridge is entirely different from the one in the Shenandoah Valley or the little one on Cranberry Island, Me., the only others I have seen. Natural bridges at best are rare phenomena, and the one at North Adams is unique, as far as I know, in being formed of a true marble.

Stated Meeting, held Wednesday, December 12, 1900.

SUBTERRANEAN WATERS.

By Charles Morris.

The crust of the earth is only in a general sense a solid mass. In many localities it might be compared to a sponge, full of cavities and ramifying passages, and freely permeable to liquids. While in many places it is composed of dense rock or firm clay, through which water cannot make its way, in others it is rent and splintered, and large cavities here and there exist. Again, much of the material of the crust is porous, water passing somewhat freely through it, and in other localities water makes its way by a process of solution, dissolving and carrying off certain constituents of the rocks. As a result of this permeable condition much of the water which falls upon the earth's surface makes its way into the interior, penetrating the pores and cavities of the crust, which seems to be fully saturated with water.

What may be the actual quantity of water thus held in the earth's crust it is far beyond the present power of science to decide. It must be very great, since, in addition to the free liquid, water exists as a constituent of the hardest rocks. If restored to the surface it would doubtless be sufficient to raise considerably the ocean level, and perhaps to flood all the lower portions of the dry land. In that

remote period when the heated condition of the crust prevented the inflow of water, and the whole of earth's liquid element swelled the ocean, such a condition very probably existed. For ages, as the crust cooled, the waters made their way into the interior, until they reached a considerable depth, and the depression of the ocean level permitted a large section of the surface to emerge as dry land. One important result of this cooling of the surface and narrowing of the oceanic basins has been a decrease in evaporation and rainfall and a localization in the distribution of atmospheric waters, so that large regions of the surface have become deserts. This process of desiccation will doubtless continue in the future, but with great slowness, since the cooling of the earth's crust has become a very deliberate operation.

The quantity and distribution of the liquid contents of the crust are very imperfectly known. We can become aware of their distribution only by the upflow of water through springs and the piercing of the surface with wells. It is of interest to find that water exists at some level in almost every locality where such a well has been sunk, and that it is abundant at some of the greatest depths that have been reached, frequently under sufficient pressure to rise to the surface. There are, of course, vast reaches of strata destitute of water in a free state, but these dense strata have failed to check the downflow of the liquid element. Pierce them, and water is found below; pierce still lower strata, and water again outflows, often in large volume. Like the rocks themselves, the liquid contents of the crust seem to exist in successive strata, growing warmer as they lie at greater depths, and usually bearing mineral matter in solution, the product of the rocks through which they have made their way.

An interesting analogy may be shown to exist between the crust of the earth and the human body. The latter, solid exteriorly, is everywhere permeated with streams of flowing liquid, which pours forth wherever the surface is pierced. In the same manner, if we pierce the earth, its life blood gushes out, now flowing quietly, as from a vein, now spirt-

ing freely, as from an artery. Wherever we break through the skin of the great body of the earth the same results appear. In some of the most unpromising localities an abundance of subterranean water seems to exist. Even under the arid surface of the Sahara, the most extended of the earth's deserts, there appears to be an abundant supply of water at a moderate depth, which oozes forth freely at almost every point where an artesian well is sunk. The arid region of Southern California is partly irrigated from a similar subterranean stratum, and like conditions exist in other desert regions of the earth's surface, natural springs oozing up where artificial ones have not been made.

From this we may deduce that, so far as subterranean water is concerned, there is no marked difference between regions of abundant rainfall and those of great aridity. Dry as the soil may be in one locality, moist as it may be in another, the boring-rod of the well-driver reveals a strikingly homogeneous condition in the depths of the crust, and an oasis is formed in the desert wherever there is a passage upward for the underground waters.

There is nothing surprising in this. Such a distribution of the subterranean waters is what we might naturally expect to find. Once penetrate to the sub-surface and we reach a region in which the diverse influences of aridity and precipitation fail to assert themselves. Though the surface distribution of water may be localized, the movement beneath the surface is likely to be general, the water following every channel and making its way by multitudinous avenues to regions far removed from its place of origin. While the surface water may flow through river channels to desert regions, the underground distribution is likely to be more general, since, while the surface represents but a single stratum, there are many underground strata, each affording special opportunities for distribution. While the arid regions of the surface are those of small rainfall, those of the interior are due to impermeable rock strata, and the two conditions are not likely to coincide. It is quite conceivable, indeed, that there may be a far more abundant supply of water beneath a desert than beneath a well-watered

region, if the strata in the former case are more permeable than in the latter. The movements of subterranean waters have been going on for ages, and their existing distribution is dependent far more upon freedom of underground flow than upon variation in surface rainfall.

If, now, we come to consider the conditions under which the interior water exists, it is impossible to accept a wide-spread popular conclusion to the effect that flowing streams and rivers of water exist in the depths of the earth's crust. Streams of this character are found in great caverns, and this has doubtless led to the conception that the underground waters exist largely as rivulets or rivers, flowing through interior channels as the blood flows through our veins.

The fact is, however, that, apart from the streams found in the cavities in limestone strata, which must somewhere find a passage to the surface, such conditions do not and cannot exist. There are no such deep-lying streams, no great rivers flowing within the earth's crust; the subterranean waters being either at rest, or moving sluggishly as they are drawn off.

The interior of the crust was, in all probability, saturated with water in far remote times, and it is impossible for this water to move except to the extent that it finds a surface vent. It is probably contained almost wholly in porous rocks, and but to a small extent in channels and cavities. For the same reason the inflow is limited, being dependent upon the outflow. A saturated sponge can take in no more water, even if plunged into a full vessel. And there can be no movement of water into its interior, except to the extent that water escapes from its surface. In like manner, if the earth's crust be once saturated, all its pores and cavities filled, no more water can enter, and there can be no movement of the water within except to the extent that the contained liquid has an opportunity to escape.

The most evident channels of escape are those of springs, yielding cold, warm or hot water as they come from varied depths. These are rarely sufficient in number or volume to create any active interior movement, and most generally have to do with superficial strata. They are not confined

to the land surface, but frequently open under water, occasionally forming the sole supply of lakes. As one example of this may be instanced Lake Bombon, in the island of Luzon, which has no visible inflow, but has a considerable river for its outflow.

The well may be regarded as an artificial spring, which taps water strata of varied depths, occasionally, no doubt, reaching very ancient accumulations, which have lain undisturbed for ages. If irrigation wells increase very largely in number, as they seem likely to do in the future, they may give rise to a somewhat active movement of the interior waters. The artesian outflow is, of course, limited in quantity, since the sources from which it draws need to be renewed from the surface, and the seepage downward is a deliberate process and not calculated to yield a rapid new supply. The quantity of water to be obtained from the earth's crust is, therefore, far from inexhaustible, and represents a supply that has been gathering for ages. It may be said further that this water cannot reach the surface except through the influence of pressure, this being usually, perhaps solely, a hydrostatic pressure operating from some supply of water at a higher level, and indicating that the interior waters are to a large extent in continuous contact. It may be, indeed, that the pressure of natural gas has its share in the upflow of water, as it probably has in that of petroleum.

As regards the depth to which water can descend in the earth's crust, it is to a large extent an open question. Professor King, in his able study of this subject, considers that water may reach to a depth of more than 10,000 feet, —how much more he does not venture to suggest. If the crust were permeable to an indefinite distance downward, and water could descend unchecked, a vast volume would be necessary to produce saturation, but there can be no doubt that the rocks grow denser and less permeable as depth increases. The elevation of mountain ranges and the deposition of thick strata of new rock material have undoubtedly greatly compressed the underlying rocks, decreased their porosity, and forced out much of their more

ancient water contents, and it is possible that in this way a limiting layer may eventually be formed through which no water can penetrate. Yet at any time the rending action of earthquakes seems capable of opening vast rents in the deeper rock layers, producing cavities sufficient to contain large bodies of water, and to permit the descent of this liquid element to much greater depths.

There appears to be a limiting agent different from this, and one not subject to the action of chance or accident, or to the possible existence of porous rocks at a much lower level than has been estimated. This is a stratum of heat, not of dense rock, and one that seems likely to constitute an effectual limit to the descent of water, its action being to reverse the descending tendency of the liquid substance and convert it into an ascending tendency. In other words, the heat at a certain depth must be sufficient to convert the water into steam, which seeks to force itself upward with an energy greater than that with which the superincumbent water seeks to descend. The pressure of water at great depths, it is true, considerably raises the evaporating point, but there is a limit of temperature at which no amount of pressure can overcome the tendency to vaporize, and where this degree of heat is reached the possible descent of water comes to an end.

There are facts which seem to indicate that this limiting layer of temperature varies in depth to a large extent in different regions of the earth. In the Yellowstone Valley, for instance, the phenomena might be held to prove that the inflowing water is converted into steam at a very moderate depth. The multitude of hot springs, the leaping geysers, the whole phenomena of the valley, appear to indicate a high degree of heat at no great distance beneath the surface, a temperature sufficient to vaporize the descending water and hurl it up again in boiling fountains. And the same might be held to be the case in the various other geyser regions of the earth.

This is only one of the phenomena supposed to be due to the conflict between water and heat in the earth's crust. There is another and a far more important one, that of

volcanic eruptions, which are by many held to be results of the conditions here considered. In the geyser, the steam and water have open vents and are free to escape. In the volcano the vents are closed and the imprisoned giant of steam has to force its way to the surface. The boiling lava, which here replaces the hot water of the geysers, is saturated with the water to which its force of uplift is due, and this, as it reaches the surface, flashes again into steam and rends the lava into dust, or so-called ashes. The earthquake, which so often accompanies the eruption, is a result of the same cause, and testifies to the throes of the imprisoned giant in its mighty effort to break its bonds. The whole phenomenon is a striking example of the limitation of the descent of water through the influence of internal heat. This view, of course, is hypothetical, but as an instance in its favor I may refer to the remarkable eruption of Krakatoa in 1883. The suddenness and extreme violence of this eruption suggest the probability that some new opened crevice or cavity admitted the ocean waters in great volume to the heated strata of the mountain depths, and that these waters were converted explosively into steam, which expanded with a force sufficient to blow the mountain into fragments and hurl its debris miles into the air.

While it is possible that the existence of geysers and volcanoes indicates marked differences in the depth of the superheated rock layer, this is by no means necessarily the case. It may simply indicate that they occur in the localities in which the crust is specially permeable to water, and that such results are likely to occur wherever water is able to make its way downward to a sufficient depth. It may be suggested that unbroken strata of dense rock check the deep descent of water throughout the greater part of the earth's crust, and that it is able to reach the superheated strata only in the limited localities to which the phenomena in question are confined, and also that some of the effects named are likely to appear wherever and whenever the subterranean water does penetrate to this depth.

These considerations lead to the interesting conclusion that the most vigorous activities of the earth's crust—the

volcanic eruption, the earthquake and the geyser—may be largely or wholly due to the action of subterranean water. The same may be said of other activities of the crust. The slipping of strata, to which some earthquakes are credited, may be caused by the solvent action of water, and the lateral pressure to which mountain elevation is due is held to be a result of surface denudation and the heaping up of new strata beneath the ocean waters.

There is a second very important service rendered by water, that of the cooling of the earth's crust. In the primeval period the surface waters were constantly rising as vapor and conveying the superficial heat upwards, to be radiated from the atmosphere into space. In the succeeding period the subterranean water became engaged in similar service. Heated in the lower strata, it rose as the hot spring or the geyser, and in the form of explosive steam it hurled great masses of molten rock to the surface, there to yield its heat to the air. The volume of heat thus conveyed in a century to the surface is very considerable, and in former times was probably much more so. It may much exceed that which reaches the surface by the slow process of conduction.

Subterranean water would thus appear to have long been an agent of the utmost service to the earth, giving rise to the great activities of the crust and aiding essentially in cooling its interior. What will be the future record of this useful agent it is difficult to say. As the crust continues to cool, the waters may make their way to lower depths, unless checked by a general layer of impermeable rock. The cooling of the rocks will also tend to make them more capable of water absorption, and it has been suggested that the ocean waters may all eventually be swallowed up in this way, and the earth become a dry and dead planet like the moon.

This at least we can be sure of, that if such an event takes place it will be at some very remote period in the future. The seepage of water into the earth has long been decreasing with the decrease in the area of rainfall. If the oceans should grow narrower by the partial absorption of

their water, the rainless area will grow still more extensive and the area of seepage become more contracted. Civilization is adding to this effect by the removal of the forests. The water once held in their mold and gradually penetrating the surface now hastens downward to the streams and adds much less than formerly to the subterranean supply. As desiccation increases nature will continue what man has begun, the forest area narrowing and the waters rushing with less resistance to the sea. These influences must greatly check the possible future disappearance of the ocean waters within the crust, and whatever the final result may be, many millions of years must pass before the earth can become, from this cause, unfitted for the habitation of man.

DISCUSSION.

PROF. F. L. GARRISON suggested that some of the effects which Mr. Morris attributed to underground action might more probably be due to atmospheric conditions, such as aridity, etc.

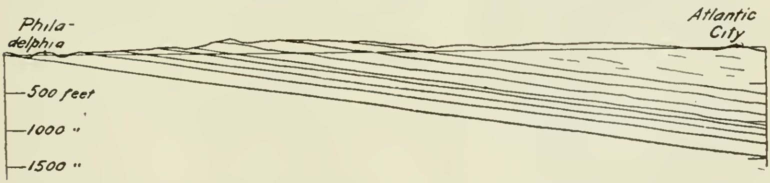
MR. J. C. TRAUTWINE, JR.:—In connection with the water supply of Philadelphia, suggestions have been received from time to time looking to the utilization of subterranean supplies by means of artesian wells.

From what I know of the geology of Philadelphia, and of the gneiss and mica schist upon which it appears to rest, I have always been skeptical as to the existence, under the city, of strata favorable to the formation of true artesian wells, which, I have supposed, could hardly be looked for below the relatively ancient rocks which immediately underlie the Philadelphia clays and gravels. I should be glad if any light could be thrown upon this branch of the subject.

DR. HENRY LEFFMANN:—Whatever may be the nature of the waters under the earth in this region, it is a matter of experience that deep wells generally yield a supply, but that the quality and quantity are often unsatisfactory. In many cases the water contains so large an amount of iron compounds as to be unsuitable for ordinary uses. Several wells in the business section of the city have been aban-

doned for this reason. Chlorides, principally, of course, sodium chloride, and calcium compounds, are also apt to be present in large amounts. A well of about 533 feet deep near the mouth of the Schuylkill River yields water containing considerable sodium chloride, but little of other substances, and this water has been used for some time both by human beings and farm animals for drinking without apparent injury. A well at Ninth and Mifflin and one near Hestonville also yield good waters. On the other hand, a well over 2,000 feet deep, near Broad and Green Streets, yields but little water, and, judging from my analysis, this is derived from the subsoil and not from a deep water-bearing stratum.

MR. JAMES CHRISTIE mentioned artesian wells in and near the northern portion of the city, especially in the neighborhood of Pencoyd, which yielded fairly, but the water of which was highly impregnated with magnesia, so much so that the employés of the Pencoyd Iron Works complained of intestinal troubles as a result of using it.



MR. TRAUTWINE sketched upon the blackboard a geological cross-section of Southern New Jersey between Philadelphia and Atlantic City, as given on a map prepared by the New Jersey State Geological Survey, showing alternating strata of sand and marl sloping gently from the Delaware River to the Atlantic Ocean, and underlaid, at least in the vicinity of Philadelphia, by the older rocks already mentioned. It will be seen that, according to this section, the deep artesian wells sunk near the seashore really tap the outflow from the vast natural sand filter bed formed by the sandy plains of Southern New Jersey, those nearest the coast intercepting the greatest number of these water-bearing strata, while near the Delaware River only the lower most of these strata are met with.

During recent years a company proposed to make a large excavation close by the Delaware River on the New Jersey side at Palmyra, opposite the Lardner's Point or Frankford Pumping Station of the Philadelphia Water Works. This excavation, it was argued, would be filled with pure water which could then be led in pipes laid under the river to the Lardner's Point Station, and thence pumped to reservoirs or into the distribution instead of using the unpurified Delaware River water as at present.

In correspondence had in connection with this scheme, the promoters expressed the view that the excavation would be filled by water drawn from the State of New Jersey in the near vicinity, but it has always seemed to me that if reliance can be placed upon the cross-section here shown, we should expect rather that the excavation would be filled by water filtering into it from the Delaware River through the intervening mass of sand and silt.

DR. LEFFMANN:—I do not know what data Mr. Trautwine's correspondent has that should lead him to reject the view that the water-bearing strata in New Jersey are inclined so that they are deepest at the seashore, but I should require a thorough exposition of his argument before I would abandon the views that have been so carefully worked out in connection with the geology of New Jersey, especially by Mr. Lewis Woolman.

I have found the water yielded by the new artesian wells at Camden analogous, in composition, with filtered Delaware River water. At Atlantic City, the artesian wells at Haddon Hall, and other wells of about 800 to 900 feet depth, gave a very satisfactory water, low in total solids, while both the deeper and the shallower wells gave much less satisfactory water, and wells sunk midway between Atlantic City and Philadelphia gave water heavily charged with iron. The water of the artesian well at Asbury Park is heavily charged with iron in solution, which, by the action of the air injected into it by the Pohlé air-lift pump, becomes further oxidized and reaches the surface carried in suspension, and is filtered out.

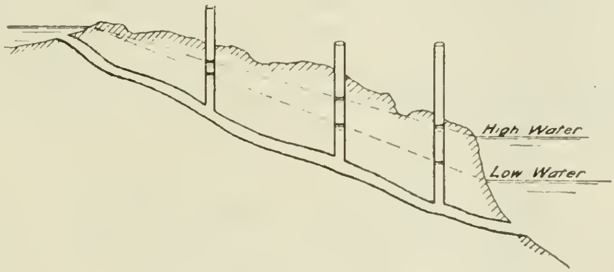
Geyser waters are very rich in silicic acid. In this

respect they differ from most deep waters, and it is probable that a powerful dissociation action takes place when very hot water under pressure comes in contact with the ordinary rock silicates.

Apropos to this, I may mention a laboratory experiment in which I was obliged to immerse a glass vessel for some time in hot water under high pressure. The glass in this case showed evidence of having been attacked and partially dissolved by the water.

Mr. Christie mentioned a fresh-water well near the sea-shore, the level of which rose and fell with the tide.

Mr. Trautwine:—The rise and fall of the level of the water corresponding to the rise and fall of the level of the tide may readily be explained by the accompanying sketch illustrating the flow of water from a higher to a lower reser-



voir through a pipe provided with piezometers, or tubes indicating the pressure.

As the water flows from the higher reservoir, through the pipe, to the lower reservoir, the levels of the columns in the piezometers gradually become lower as we proceed from the upper to the lower reservoir; for, in each portion of the pipe, a part of the pressure existing at the upper end of such portion is expended in overcoming resistances in such portion.

If now, by any cause, as by the fall of the tide in the ocean, the level of the lower reservoir be lowered, that in the upper reservoir remaining constant, the hydraulic grade (or line joining the tops of the columns in the piezometers) will be correspondingly lowered.

The lowering of the level in the lower reservoir, of course,

increases the total head under which the water is flowing, and which is equal to the difference between the water levels in the two reservoirs. This increase in the total head causes an increase in velocity throughout the pipe, with a consequent diminution in the pressure at each point.

This seems to be in general analogous to the case of wells supplied from a higher district further inland, each well being in fact a piezometer standing upon the water-bearing stratum through which the flow is proceeding outward to the ocean, and it is therefore only reasonable to expect that the levels in these wells, especially those near the sea, would show a correspondence with the levels in the ocean.

DR. LEFFMANN:—I think it would be a great mistake to limit the term artesian to wells that furnish water that rises above the surface level; the true distinction is that the water is obtained from a stratum that is separated from the subsoil by one or more impervious layers, and is, therefore, not derived from the rain, surface or subsoil waters of the immediate district.

CHEMICAL SECTION.

Stated Meeting, Thursday, January 24, 1901.

A BRIEF SKETCH OF THE ESSENTIAL REQUISITES OF "POWDER" AS DISTINGUISHED FROM "EXPLOSIVES."

BY DR. W. J. WILLIAMS.
(Being the Address of the Retiring President.)

In many minds, probably, the question arises, "What is the difference between a 'powder' and an 'explosive?' Are they not 'almost synonymous,' or at any rate are not all powders also 'explosives?'" In the ordinary acceptance of the terms the reply would be "yes," and yet in the military technical use of the words the difference is great.

"Powder" is a means of propulsion for projectiles. "Explosive" is a means for production of powerful shattering effects.

Explosives, in the broad use of the term, are classified by Berthelot in eight distinct groups, which may be summarized thus:

First group. Explosive gases.

Second group. Gaseous mixtures capable of detonation, formed by the combination of chlorine, oxygen or nitrogen oxides with hydrogen or hydrocarbon gases or vapors.

Third group. Explosive inorganic compounds that can be detonated by shock, friction or heat.

Fourth group. Explosive organic compounds, definite bodies, solid or liquid, that can be detonated by heat, friction or shock; for example:

(*a*) Nitric esters or nitric ethers, such as nitro-glycerine.

(*b*) Nitric derivatives of carbohydrates, viz., cotton, paper, wood, cellulose and sugar, dextrine, etc.

(*c*) Nitro derivatives of aromatic hydrocarbons, such as tri-nitro-phenol and its salts, etc.

Fifth group. Mixtures of definite explosive compounds with inert bodies. Any of the preceding explosives can be mixed with inert materials to moderate their powder; for example, dynamite, wet gun-cotton or camphorated guncotton, or gun cotton soaked in paraffine.

Sixth group. Mixtures of an explosive oxidizable compound with a non-explosive oxidizer, to complete the combustion.

Seventh group. (*a*) Mixtures with an explosive oxidizing base, a mixture of an explosive with an excess of oxygen (nitro-glycerine) with an oxidizable body, such as carbon-dynamite.

(*b*) Analogous mixtures in which the oxidizing and oxidizable substances are both explosives, such as blasting-gelatine, gum-dynamite.

Eighth group. Mixtures of oxidizable and oxidizing bodies neither of which is explosive separately, which include black powder, $KNO_3 + S + C$, and powders formed by mixing hydrocarbon compounds, charcoal, coal, wood, cellulose, starch, etc., or sulphur and metals with nitrates of potassium, sodium, barium, lead and many others.

The substances enumerated above are all "explosives,"

but very few, however, could be classed as "powders," and I will endeavor to show some of the essential requirements of a "powder" as distinguished from an "explosive."

Explosives may be subdivided into two classes, "explosive mixtures" and "explosive compounds." "Explosive mixtures" are intimate mechanical mixtures of components, but these components are not in chemical combination.

In "explosive compounds" the elements are chemically combined, producing an explosive wherein the combustible and the oxidizer are both contained in the same "molecule;" hence it is easy to understand that its action is infinitely more sudden and violent than that of the most intimate mechanical mixtures.

Explosive compounds may be divided into five classes, according to Major J. P. Cundill, R.A., and Lieutenant W. Walke's very convenient classification, which may be summarized as:

(1) Nitro substitution compounds.
(2) Nitric ethers or esters.
(3) Explosives of the Sprengel class.
(4) Fulminates, amides and similar compounds.
(5) Smokeless powders.

Many persons well acquainted with the chemistry of explosive compounds apparently fail to grasp the military technical difference between explosives and powders. The general idea seems to be, the more energy and power that can be condensed in a given weight, the better the explosive or powder. While the storage of great power is a most important element of the problem, yet there are others which require careful consideration in the production of a good service powder.

In general terms of differentiation one might define a "powder" as an explosive wherein the chemical changes are comparatively slow or progressive, or that the whole of the power is not released in the shortest possible period of time, but gradually, progressively, and if possible at a uniformly increasing rate. An "explosive," on the other hand, should develop its total energy in the shortest possible period of time; concentrated, as one might say, in one

powerful shock. Briefly, a powder *pushes.* An explosive *strikes* a sudden smashing, shattering blow. A powder *burns;* an explosive *detonates.* What then are the essential, and to some extent distinctive, requisites of a "powder?" These may be summarized as follows:

(1) The velocity developed.
(2) The pressure attained.
(3) Specific gravity and gravimetric density.
(4) Granulation.
(5) Temperature attained during combustion.
(6) Susceptibility to ignition.
(7) "Smoke" and ash.
(8) Friability.
(9) Sensitiveness to shock.
(10) Suitability for loading by machinery.
(11) Sensitiveness to environment, such as heat, moisture, etc.
(12) Stability.

Let us consider the first two conditions:

(1) The powder should develop a high velocity of projectile, and

(2) The pressure must be kept within prescribed limits, fixed by the strength and endurance of the gun.

To fulfil the first condition, the evolution of gas should be continuous and at an increasing rate to keep up a well-sustained pressure on the base of the projectile, because, as the projectile travels, the area of chamber (gas) space is constantly increasing; yet, to fulfil condition No. 2, the gas must not be developed too fast or the pressure on the barrel becomes too great. These two conditions alone present a very pretty problem, viz., to obtain highest possible velocity, *i. e.*, propulsive effect, and yet to keep the pressure within well-defined limits. The velocity of the ·30-inch caliber Krag-Jorgensen rifle bullet should be at least 1,960 feet per second (53 feet from muzzle of rifle), while the pressure should not exceed an average of 38,000 pounds per square inch, with a maximum of 45,000 pounds for any single round.

(3) Specific gravity and gravimetric density.

As we have already seen in the case of powder, a high velocity must be attained, yet with comparatively low pressure; and here comes in a third condition which, while not obligatory, is very desirable, viz., the power should be contained in a quantity of powder *limited by the content of the powder space in the cartridge case now in use*, to obviate the necessity of constructing arms of a new pattern to suit the new powder. While this space is not an absolutely fixed quantity, yet it is confined within very narrow limits. Obviously it cannot exceed the total cubical content of the case between the primer and the base of bullet; it may, however, be somewhat less, as this space need not necessarily be entirely filled. This question reduces itself then to a consideration of the specific gravity, the gravimetric density and the granulation of the powder. Specific gravity is so well known a term that there is no need to define it. In the case of a "powder" it is a secondary consideration, though of greater importance in an "explosive." On the other hand, gravimetric density becomes an important consideration. This is not easy to define; perhaps the best definition is that given by Lieut. Willoughby Walke, viz., "as the ratio which the weight of a given volume of the substance, including air and other interstitial spaces, bears to the weight of an equal volume of the standard (water) taken at 15·5° C. and 760 millimeters." As it is generally assumed that 1,000 ounces of water occupy a cubic foot, the gravimetric density is usually represented in terms of "ounces per cubic foot."

In the case of "powders" intended for the ·30-inch caliber rifle now in service, the gravimetric density is one of the points to be considered. It should be such that from 30 to 40 grains will, at least approximately, fill the powder space of the cartridge case. The gravimetric density is to some extent a question of "granulation" or of the form of grain in which the powder is manufactured, and to some extent a question of the ingredients of the powder.

It is obvious that gravimetric density is not dependent on specific gravity. A very dense powder may show a much lower "gravimetric density" than a powder of low specific gravity.

With explosives for shells, or bursting charges, the case is somewhat different. Here the object is to get as much potential energy as possible (not taking "sensitiveness" and other qualities into consideration) into a given space. In this case, then, a high gravimetric density is desirable. On comparing explosives about equal in gravimetric density, the one with the higher specific gravity is the better adapted (other qualities not now being considered) for such purposes, as it is obvious that the higher the specific gravity, the greater is the potential energy "maximum effort" developed by equal volumes of explosive. If possible, an explosive should be packed solid in a shell, avoiding air spaces and making its gravimetric density as nearly equal to its specific gravity as possible.

Briefly, and in general terms, for powders the gravimetric density must be such as to fulfil the conditions given above; for explosives, generally speaking, a high gravimetric density and specific gravity are desirable.

(4) As mentioned before, the "granulation" of a powder is an important factor in determining its gravimetric density. It is also of importance from another point of view, as the shape and size of the grains determine to a large extent the speed of combustion, and consequently the "velocity" imparted to the projectile and the "pressure" exerted on the gun, which is dependent on the evolution of gas at the proper rate as the projectile moves forward in the barrel. Opinions differ largely as to the best form of grain. It is generally conceded, however, that to meet the requirements of the case the ignition surface should be as nearly constant as possible. This is especially desirable in rifles of large caliber. Hence cannon powders are manufactured generally either in thin flat, or sometimes striated, strips, or as cylindrical rods or cords, solid or preferably perforated either with a single longitudinal perforation, ⊙, or more often with several longitudinal perforations, thus  It is obvious that, as combustion proceeds, the area of exterior surface is constantly diminishing; but as the area of each of the perforations (or channels) is constantly increasing, this tends to keep up an approximately

constant evolution of gas. Moreover, as the rate of combustion increases with the pressure, this also tends to accelerate the evolution of gas as the charge is in process of combustion. The best or most effective form of grain for cannon is, as yet, an undecided question. Some experts favor one form, some another. The size of the grain varies with the caliber of the piece. Guns of 3·2 inches diameter take a grain about ½ inch long by ¼ inch diameter. Larger caliber guns have larger grains proportionately as the weight of charge increases. The larger the grain, the slower the rate of combustion, other things being equal.

For ·30-inch caliber rifles the granulation is, of course, much smaller. The grains are measured by sieving and should be of such a size as to pass through apertures 0·06 to 0·08 inch diameter and be held on a sieve with apertures 0·03 inch diameter.

Some rifle powders are made in the shape of thin flat discs, nearly square, measuring about ·075 inch by ·075 inch by ·01 inch thick; some cannon powders of the same shape, but of larger dimensions, about ·4 inch by ·4 inch by 0·025 inch.

For revolvers the grain is usually finer and smaller than rifle powder. It passes through 0·03-inch apertures and yet is a distinct grain and *not* fine dust.

(5) It is very desirable that the temperature attained during the combustion of the powder charge should be kept as low as possible, for the greater the heat developed, the greater the erosion or wear of the bore of the piece. This not only rapidly destroys the weapon and shortens its length of service, but also impairs its accuracy and reduces the velocity of the projectile in a comparatively short time on account of the escape of gas around the projectile while it is passing over the eroded portion of the bore. For this reason many consider nitro-glycerine a somewhat undesirable ingredient in smokeless powders, and its use is avoided, in a greater or less degree, especially when heavy charges are required. Others consider the advantages of nitro-glycerine more than balance its objectionable quality of producing very high temperatures and consequently con-

siderable erosion, and continue its use, seeking to modify its erosive action by admixture of hydrocarbons as coolers. The superior balistic qualities of nitro-glycerine powders are due to the heat produced by more perfect combustion, the nitro-glycerine furnishing the oxygen. This best preserves the tension of gases and sustains the pressure.

The powder used in the British service, cordite, contains as much as 57 per cent. nitro-glycerine, but it is said the guns rapidly deteriorate from erosion. The further discussion of this point is, however, outside the scope of this paper.

(6) A powder should be readily ignited by the service primer. It is, of course, essential that ignition should not fail (or cause "miss-fires") nor be delayed (producing "hang-fires"). Difficulty of ignition is therefore a serious defect in a powder, while at the same time too easy inflammability is equally undesirable, though this objection is seldom met with in smokeless powders which have been properly manufactured and granulated.

(7) In these days when the advantages of a practically "smokeless" powder are established beyond question, it is scarcely necessary to advert to the fact that mineral salts, leaving unconsumed residues, or "ash," on combustion, are inadmissible in any than very small proportions. So-called "smokeless" powders are not absolutely smokeless; they leave a thin, hazy vapor which is quickly disseminated. Small admixtures of mineral salts may be permitted in service powders. From a practical point of view the ingredients of a service powder should leave very little ash on combustion, and consequently very little smoke. So-called smokeless powders for *sporting* purposes often contain large proportions of mineral salts. The production of a little smoke is of no particular consequence under the conditions, and the admixture of mineral salts naturally enables the manufacturer to make a much cheaper article, yet one fully equal to all the requirements of the case. In explosives used in field and siege shells the production of smoke is advantageous in that it permits observation of point of burst and correction of aim and interferes with similar observation of his own practice by the enemy.

(8) Another point which is of high importance and yet is frequently entirely overlooked, is the friability of the powder or grain. A friable powder, the grains of which are easily broken, or one which easily rubs to dust from the attrition of one grain against another, during transportation or any other cause, is very undesirable. The presence of powder dust in a cartridge may be a source of great danger, as the dust ignites with great rapidity, causing undue pressures and strains on the weapon, and, indeed, occasionally causing (or at any rate presumably causing) such rapid combustion that it amounts to detonation.

The grain should, therefore, possess a considerable degree of toughness, or at least should not show brittleness.

In large grain cannon powders similar effects may be caused by the development of cracks in the grain, which means practically the multiplication of perforations, and, therefore, the increase of burning surface, resulting in great rapidity of combustion and possibly dangerous increase of pressure, which in extreme cases may also amount to detonation.

As smokeless powders are now "colloided," they are generally of a tough nature, very much like horn, yet occasionally they exhibit signs of friability in small grain powders, and of cracking in large grain powders, which is probably due to their having been dried too hurriedly, which causes too quick and uneven shrinkage, or these qualities may be due to the use of too large a proportion of solvent during the colloiding process. But no matter from what cause, friability and cracking are considered defects of the greatest importance.

(9) A powder should not be unduly sensitive to the shocks of ordinary transportation and handling. This is a defect scarcely ever met with under the present method of manufacture, where the more sensitive substances, such as nitro-glycerine, are so thoroughly incorporated with more insensitive substances, such as colloided gun-cotton, that there is no exudation of liquid nitro-glycerine. The present methods of colloiding have practically made exudation almost impossible. It is not often one meets with an unduly sensi-

tive powder—most of them withstand ordinary shocks very satisfactorily. An explosive intended as a bursting charge for armor-piercing shells should possess the power of sustaining extremely severe shock without explosion.

(10) A point frequently overlooked is the importance of having the powder in such a form as to be easily handled in the loading machines. Of course, if a powder is of good quality in other respects, save that it is not well adapted to the standard loading machines now in use, these machines can, as a general rule, be modified to meet the special requirements of such a powder; but the expense involved is great, and the said powder must show marked advantages over those now in use to warrant such a departure from existing conditions.

(11) A good powder should be able to withstand variable atmospheric and other conditions to which it is liable to be exposed during service or transportation, or similar conditions.

(*a*) *Heat.*—A powder may be required for use in every variation of climate from tropical to arctic conditions. The general effect of heat is to accelerate combustion and consequently increase the pressure in the weapon and the velocity of the projectile. A powder, then, to meet the service requirements in small arm rifles, must be such that exposure to a moderate heat—about 130° F.—must not increase the velocity above 100 f. s. from the standard nor the pressure above 45,000 pounds per square inch, either when the powder itself has been so exposed and is loaded into cartridges immediately, or when cartridges already loaded are so exposed and fired warm. It will be readily understood that exposure to a tropical temperature must not cause any chemical or other change. For instance, high temperature must not cause exudation of nitro-glycerine nor liquefaction of that or any other ingredient, nor loss of any ingredient by evaporation, nor decomposition of any kind.

(*b*) *Moisture.*—Exposure to an atmosphere saturated with aqueous vapor should not exert any marked deleterious influence on a powder. The general effect of such exposure is to reduce the rapidity of combustion and so diminish the

pressure in the arm and consequently the velocity of the projectile. If the small arm velocity is reduced 100 f. s. below standard, such a powder is not suited to service conditions. Of course, too, moisture has the effect of increasing the difficulty of ignition, and therefore causing "miss-" and "hang-fires." These remarks refer, of course, to powders which contain no especially hygroscopic ingredient (*e. g.*, sodium or ammonium nitrate), but yet can absorb a small percentage of moisture when exposed to a damp atmosphere. A good powder, then, should be able to resist moisture, and even if accidentally it becomes exposed to moisture it should be so constituted that when dried, either by exposure to ordinarily dry air or by artificial heat, it recovers its original condition and properties.

For "explosives" in the sense of "bursting charges" for shells, or for blasting purposes, this power of resisting moisture, or absence of hygroscopic properties, is not so essential, for when enclosed in the shell, or properly prepared more or less water-resisting case, the explosive is protected from these influences, and under ordinary conditions of storage retains its serviceable conditions. It is obvious, however, that service powders, whether for military or naval use, should be so constituted as to be practically non-absorbent, and for explosives this quality is very desirable.

(*c*) *Cold.*—A good powder should not be affected by cold, and should stand exposure to at least *minus* 40° C. for at least six hours without serious variation of its qualities. The effect of cold on the nitro-glycerine in dynamites is too well known to be dwelt on in this paper, and alternate heat and cold is apt to cause exudation or separation of the nitro-glycerine from its absorbent. It may be mentioned, however, that exposure to *minus* 40° C. does not have any material influence on well-made powders consisting of nitro-glycerine with gun-cotton; and certain other substances appear to be but little affected.

(12) All powders and explosives should be "stable," *i. e.*, there should be no decomposition by the reaction of one ingredient on another or by the influence of heat, light,

moisture, change of climate, etc. For instance, a rifle or revolver powder finely subdivided must withstand a temperature of 65½° C. for at least twenty minutes without emitting acid vapors as indicated by the discoloration of potassium iodide and starch paper partially moistened with dilute glycerine.

A cannon powder cut into thin slices about 0·020 inch thick should not cause discoloration under ten minutes at a temperature of 100° C.

Gun-cotton dried at about 46°–47° C. to constant weight and then exposed to the air of a room to absorb its normal proportion of moisture, viz., 1·5 to 2·0 per cent., should withstand a temperature of 65½°C. for at least thirty minutes without discoloring the potassium iodide and starch paper.

From these considerations it is obvious that there must be no free acid in a powder or explosive where "stability" in this sense is required. Each ingredient must be carefully purified and all free acid removed or neutralized. Certain acids such as picric acid and other nitro-substitution compounds do not seem to affect the KI and starch paper, unless exposed for a longer time than one (1) hour or thereabouts, but as a general rule free acid or nitrogen oxides will discolor the paper very quickly.

Traces of ether act quickly, probably from the production of aldehyde. Alcohol which has slowly oxidized to aldehyde, or perhaps has undergone acetous fermentation, will discolor the paper rapidly; in general, any oxidizer will act thus, so the ingredients of a powder should not only be free from acid, but also from any substance which liberates oxygen at the temperature specified. Acetic acid rapidly discolors the paper; oxalic acid (like picric) does not seem to affect it, at any rate in less than one (1) hour.

It is well known that nitro-glycerine if not carefully washed and neutralized from all acid will slowly decompose spontaneously. Such explosives should be treated with alkaline carbonates, or carbonates of the alkaline earths, to prevent this tendency to acidification on long storage or under the influence of heat and moisture.

Even perfectly neutral nitro-glycerine will slowly de-

compose under the influence of moderate heat. If the temperature does not exceed 45° C. there is no decomposition and the nitro-glycerine remains "stable" to the KI paper. A few weeks' exposure to a temperature between 45° and 50° C. will, however, much impair the "heat test," while it is rare to find a sample of nitro-glycerine that will stand 65° C. for more than thirty (30) minutes. If, however, it stands over ten (10) minutes, it is considered stable. From 45° to 50° C. may be considered the critical temperature of nitro-glycerine.

A temperature of 180° C. explodes nitro-glycerine, though very small quantities can, with care, be raised to 200° or 210° C. without explosion.

Gun-cotton, too, will slowly decompose if the acid is not carefully washed out and neutralized. If traces of acid are present, gun-cotton will begin to decompose by mere exposure to light. Very carefully prepared gun-cotton can, as Dr. Abel has shown, be kept at a temperature of about 50° C. for several months without decomposition, and even strong sunlight does not cause its decomposition. The critical temperature of gun-cotton appears to be about 45° C., as a higher temperature is apt to decompose any but exceptionally carefully prepared samples. When gun-cotton is stored in large quantities it is customary to wet it, and dry out the moisture as required. Wet gun-cotton seems perfectly safe. Good gun-cotton ignites at about 180° C., though there is a slight variation in temperature according as to whether the heat is raised gradually or quickly.

All nitro-compounds, unless most carefully prepared and purified, are easily decomposed by comparatively low temperatures and even by exposure to light. It is, therefore, essential, even when dealing with them on the manufacturing scale, to obtain absolutely neutral products. Even traces of acidity are not only detrimental, but tend to become highly dangerous, after the lapse of a short time.

What has been said of nitro-glycerine and gun-cotton applies equally to the nitro-substitution compounds of the aromatic hydrocarbons. Unless prepared with the utmost care, they are liable to spontaneous decomposition which will probably lead to disastrous results.

The general idea, then, is that a "powder" must burn comparatively slowly, evolving gas at a gradually increasing rate, while an "explosive" should develop all its energy in the shortest possible space of time. Hence, for powders, the colloid condition in which the gun-cotton or mixtures of gun-cotton with nitro-glycerine and other explosives is prepared seems eminently well suited.

The granulation should be suited to the caliber of arm, so as to regulate to some degree at least the speed of evolution of gas and consequent pressure exerted.

"Powder" should be smokeless, while the production of smoke may be highly desirable in an "explosive."

An explosive should be highly insensitive to shock to a much greater degree than is necessary in a powder.

Perhaps this brief sketch of the requirements of a powder may be of value as roughly indicating some of the more important conditions that should be fulfilled in the production of a powder suited to the present service conditions.

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.*

BY GEORGE W. COLLES, A.B., M.E.

[*Prefatory Note.*—It is not pretended that this essay is entirely new; but neither is it a mere compilation or patchwork of others. It professes to take a broad, comprehensive review of such transforming devices as are included in its scope, or nearly allied thereto, tracing their evolution from crude beginnings to the refinements of to-day, and indicating the peculiarities of each by itself, as may seem of interest or importance, and its comparative merits or demerits in relation to others. So far as the author knows, no such treatment has hitherto been given to the subject. Although a great deal has been written in recent years, all that has as yet been written, so far as he has been able to find, is of fragmentary character, treating isolated phases or problems, and not even the single-coil rotary transformer has been accorded anything like a complete treatment. Perhaps the nearest approach to the latter is the paper of Prof. S. P. Thompson, delivered before the Institution of Electrical Engineers, in November, 1898; but this again, though furnish-

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* A thesis presented in candidature for the degree of Master of Science, in the Columbian University, May, 1900.

ing a large number of interesting facts, is fragmentary and without apparent system.

Of the present essay, the historical matter is believed to be entirely new; and so, too, the classification and comparison of the different machines. The theory of the single-coil transformer, in which centers the greatest share of interest, is mostly digested and arranged from other sources; but here, too, will be found a number of facts or distinctions which it is believed have not yet been pointed out, or given the importance due them. The mathematics of the subject has been limited to such brief and general treatment as merely to indicate the mode of procedure, while the reader has been referred to the most important papers dealing with the subject, for such further information as he might desire; and the *results* hitherto arrived at have been given. But here also the mode of treatment has been in part original, in particular the equation for the heating of individual armature coils (under "Current Relations," *supra* Note 63), and the curves of Plate XX. The author would also call attention to the attempt at an analysis of the very peculiar case cited under "Pressure Relations" (at the end), which he thinks will prove interesting, although perhaps bold, no such attempt having been made by his authority, Professor Thompson. As to practical data, but very few could be given, as unfortunately very few are as yet at hand.

All the sources of information at the author's command have been drawn upon wherever they could offer assistance in the elucidation of the subject; and references have been given to original sources, wherever possible.]

The author was tempted to add to the above the alternative title "or continuous current transformers;" but in view of the restriction of that term, as generally understood, to the meaning of "dynamotors" or motor-generators employed only in connection with continuous currents, it has been omitted. The discussion of the following pages is not, however, limited to the rotary transformer in its narrow sense, to wit, that of a species of dynamo-electric machine having an ordinary one-coil armature and provided with both commutator and slip-rings, although this, as its most important form, will receive the greater share of attention; but it is intended to be a general review of all forms of apparatus which have been devised for the purpose of transforming one form of electrical current into another, and which have rotating parts (which, as will be seen, appear to be a necessity wherever continuous currents are concerned); and, incidentally, other forms will be touched upon so far as is necessary or desirable to the illustration of the subject thus defined. In this way we shall obtain a juster view of the state and possibilities of the art than we could obtain

by considering merely the virtues and defects of the species in general use for this purpose.

The term "alternating current" (denoted by *A C*) will here be used in the sense of monophase alternating current; "direct current" (*D C*) as the synonym of continuous current; polyphase (*P P C*), 2-phase (*2 P C*), 3-phase (*3 P C*), etc., in their usual significations. As has been shown by Steinmetz[1] and others, there is a radical distinction between the simple alternating and the polyphase form of current, due to the fact that in the former the energy transmitted fluctuates from zero to a maximum, along with the current; whereas in the latter the flow of energy is constant. This fact serves to differentiate the polyphase as completely from the alternating as from the continuous current, and to place it midway between them, resembling the former in its current wave and inductive or magnetic characteristics, the latter in its energy-flow and mechanical action upon dynamo-electric machinery.

In treating of current transformation we have therefore to consider these three kinds or species of current, and we may wish to transform our electrical energy—

I. In respect of pressure (pressure transformation):
  (1) Alternating,
  (2) Polyphase,
  (3) Continuous;
II. In respect of kind (species transformation):
  (4) Alternating and polyphase,
  (5) Polyphase and continuous,
  (6) Continuous and alternating;
III. In respect of frequency (frequency transformation):
  (7) Alternating,
  (8) Polyphase;
IV. In respect of phase-relations (phase transformation):
  (9) Polyphase.

These are the nine possible simple transformations. We may, perhaps, range them more conveniently with respect

[1] *Trans. A. I. E. E.*, V. 9, p. 93, Feb., 1892; and V. 12, p. 330, June, 1895.

to the different sorts of machinery adapted to accomplish them, as follows:

(1), (2) and (9) may in all cases best be accomplished by stationary transformers; though for (9), rotary apparatus is occasionally used.

(4) is perhaps most often accomplished by stationary apparatus, although rotary is preferable in many cases.

For (3), (5) and (6), involving continuous currents, and for (7) and (8), involving frequency-changing, apparatus with moving parts, so far as we can see, must be used. We cannot say positively but that some practical stationary mode of frequency-changing may be devised; but, on fundamental principles, it appears certain, as will be hereafter more fully shown, that wherever continuous currents are concerned, no transformation, in the proper sense of the word, can be accomplished without moving parts.

The following pages will be confined principally to transformations (3), (5) and (6), which are the kinds oftenest occurring in practice where rotary transformers are desired; touching lightly upon (7) and (8), and upon the others only as may be necessary in the elucidation of our main thesis.

These simple transformations are, however, rarely found alone, but usually associated with one or more others; thus, a species transformation is usually associated with a pressure transformation, and sometimes with a frequency transformation, or both; a phase transformation may be superadded, or, as in some recent inventions, may form an intermediate step to the species transformation. The question whether all these transformations shall be made at once and in one machine, or severally and in separate machines, is one of expediency rather than possibility; for while it is, theoretically at least, always possible to construct a machine to accomplish them all, it has been often, and indeed usually, found advisable not to do so, on account of practical difficulties or defects in the apparatus so constructed. Now, the imperfection and drawbacks of such a method, to wit, the use of two or more distinct machines through each of which all our energy must pass before we get it in the desired form, both as respects high plant-cost and

low efficiency, are obvious; and it is therefore to overcoming this necessity, by the perfection of the single machine, that the future progress of the art must be principally directed—not solely to the perfection of the common one-coil rotary transformer as it exists; which, providing as it does for only one simple transformation, must always be an imperfect means of reaching the desired end.

We may, therefore, appropriately proceed by a review of existing apparatus of all kinds, considering as we go the peculiar properties of the most important types. It will be most useful to proceed by the inductive method, or in the historical order in which the improvements arose; but first marking out the several distinct types or lines of development which distinguish existing forms, and which may be summed up as follows:

I. *The Rectifier Type.*—This type is far the most ancient, dating back, according to Thompson,[2] as far as 1838, and being in common use in 1869, when they were used for the field magnets of self-exciting alternators. This apparatus can hardly be called a transformer in the proper sense, as it contains no inductive or other coils, being nothing more than a rotating commutator, whereby the pulsations of the alternating or polyphase current are commuted and rendered unidirectional, or, on the other hand, the direction of a continuous current is periodically reversed. In the former case the rectifier must be rotated synchronously by a donkey motor. A commutator of this sort is easily devised, and a number have been put on the market; but the device is crude and at best a makeshift, as no truly constant current can be produced, especially from a simple alternating current; on the other hand, a true alternating current is not produced by reversing the poles of a continuous current circuit. The main defect of this class of devices is, however, the common one of excessive sparking, owing to the fact that the circuit must be periodically broken at each reversal to avoid the alternative of short-circuiting the primary mains. The best known of these devices is perhaps the Pol-

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[2] "Dynamo Electric Machinery," Fourth Edition, p. 652.

lak rectifier,[3] which takes the current only from the tops of the waves of electromotive force, and so insures greater uniformity, though at the expense of continuity. This machine has been used in the Ferranti station at London to charge a battery circuit. We may, however, dismiss this class of machine with this brief notice as somewhat apart from our subject, as well as unimportant.

II. *The Inductorium Type.*—Characterized by a series of induction coils, which may or may not be stationary, arranged in a circle and having their primary and secondary coils, one or both, connected to the respective segments of a commutator; the apparatus is not, in general, self-rotative or self-regulating, as in our common motor-transformer, but must be rotated by a donkey-motor or other external source of power. One or two commutators are used, according as a direct and alternating or two direct currents are wanted. In this class there are three well-marked subclasses:

(1) The stationary independent coil type, in which each induction coil is wound upon a separate core, and separately connected to the commutator or commutators through slip-rings. This, the oldest of transforming devices for direct currents (if we except the rectifier), has proved, in the hands of two ingenious French inventors, one of the best, if the fatal defect of sparking can be overcome.

(2) The stationary ring type, in which the separate induction coils are now wound together all upon one ring, which has two independent sets of coils wound thereon Gramme fashion, and connected to the commutator or commutators through slip-rings.

(3) The rotating ring type, identical with the former, except that to avoid the slip-ring connection and possibly to give stability to the rotation, the induction ring is mounted on the commutator-shaft. The "dynamotor" has not been reached, as no external fields are provided.

III. *The Motor-Generator Type.*—In this is included the very simple device of an independent generator coupled to a motor on the same shaft, or otherwise mechanically connected to it. Starting thus from an entirely different basis

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[3] *Electrical Engineer* (N. Y.), V. 16, p. 238.

from either of the preceding, the two following types have been successively evolved.

IV. *The Dynamotor*[4] *Type.*—Here the two independent machines of the preceding type are merged into one—usually a single armature, sometimes two armatures, but always in one field, and always with independent primary and secondary coils; its use being practically confined to continuous currents only, with a commutator for each coil.

V. *The Rotary Transformer Type.*—Proceeding still one step further in the same lines, we reach the true rotary transformer; in which we have one machine, one armature and one coil only in that armature—in short, a dynamo of the ordinary drum or ring-wound type, but provided with two sets of connections to its armature coil, one of which *must* be a set of slip-rings for an alternating or polyphase current.

It should here be noted, that we have not taken the steps leading from the motor-generator to the rotary transformer type without serious sacrifices; for the first was at the expense of regulation, the second at the expense of a pressure transformation. So doubtful is the balance of advantage in favor of the rotary transformer, in fact, that even to-day the motor-generator is preferred in many cases, and it has not infrequently happened that, proving unsatisfactory, transformers have been taken out and replaced by the old motor-generator type.[5]

As will be seen, there are connecting links or transition forms between all these five types, and shading from one into the other.

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[4] The exceptions taken to this word by Professor Thompson and others, as both philologically bad and a misdescription, are entirely just. The lack of any other to fill its place, however, compels us to press it into use. The term "dynamotor" has come to have a more limited significance than the term "motor-generator" or "motor-dynamo," as is above sufficiently distinguished. Nor is it infrequent for a word of antecedents thus confessedly bad to be forced upon us against our will, and to obtain a place in the King's English in spite of us, as for instance, *sociology*, *ferromagnetic*, *bicycle*, *automobile*.

[5] See the discussion on "Rotatory Converters" in *Journal I. E. E.*, Vol. 27, pp. 705-717, *passim* (November, 1898).

MACHINES FOR CONTINUOUS CURRENTS ONLY.

THE INDUCTORIUM.

The earliest recorded device which can be called a transformer for continuous currents is probably that shown in Plate I, which is from the specification of a patent granted to R. K. Boyle[6] in 1875. It shows a

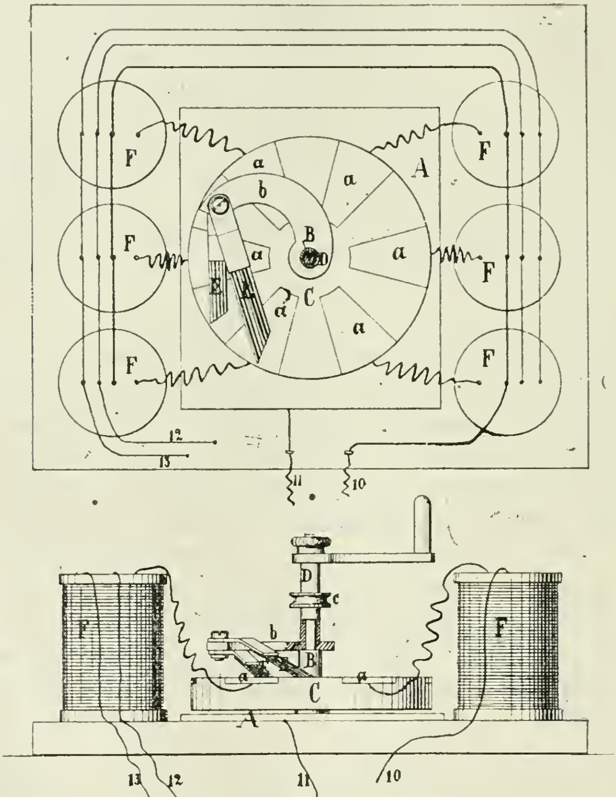

PLATE I.—Boyle's inductorium. 1875.

series of stationary induction coils *FF* whose primary leads are connected to the poles (10, 11) of a primary battery or other source of constant electromotive force, one directly, the other through a commutator *C* of the ordinary

[6] Patent No. 169,514, November 2, 1875. United States patents are meant unless otherwise indicated.

type, to each bar of which is connected the primary of one coil. The single brush (shown with two branches, *E E*) is connected to the free pole of a battery, so that, as the brush is rotated (by hand), a series of unidirectional current impulses is successively sent through each primary. This will cause electromotive forces alternating in direction to be induced successively in each secondary coil; and the secondaries being all connected in parallel, an irregular alternating E.M.F. will be obtained at the terminals 12, 13.[7] This apparatus is of the first or "inductorium" type; it is non-reversible, and would clearly be impracticable upon any considerable scale on account of excessive sparking.

A large advance over this machine is shown by the next of the inductorium type, in a patent to Van Depoele[8] issued in 1882, shown in Plate II. This machine, while still belonging to the first subtype of the above classification, shows approaches to the more modern types in several directions. *J J* are the cores of the induction coils, whose primaries are connected in regular Gramme fashion around the bars of a stationary commutator, as shown in *Fig. 4*. Direct current enters at the brushes H^1 H^2, *Fig. 5*, which are rotated automatically by the permanent magnet *K*, *Fig. 3*, which is mounted on the same shaft and immediately opposite the upper row of poles of the cores *J*. A torque is set up in this magnet by giving it a certain lead over the brushes. As the latter rotate, a current is sent through the coils, thus divided into two halves by the brushes exactly as in a Gramme ring, the current in each coil being abruptly reversed in direction as its corresponding commutator seg-

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[7] This is not the mode of operation stated by the patentee, who appears to have supposed that the unidirectional primary impulses would produce unidirectional secondary currents, the pressure being raised as desired by properly proportioning the windings. It is clear, however, that this is not the case; for, the total quantity of electricity transferred in the secondary circuit in any direction being proportional to the energy of magnetization stored up in the cores of the coils *F*, and thus being zero at the close of operations, it follows that the current integral in the secondary coils must be equally positive and negative. We cannot, unfortunately, transform continuous current from one pressure to another by any such simple and convenient method.

[8] No. 266,735, October 31, 1882.

ment is passed. A ragged alternating current is thus set up in each of the secondaries, which may be used separately or connected in series, as desired. As each coil is practically independent, there can be nothing like evenness or

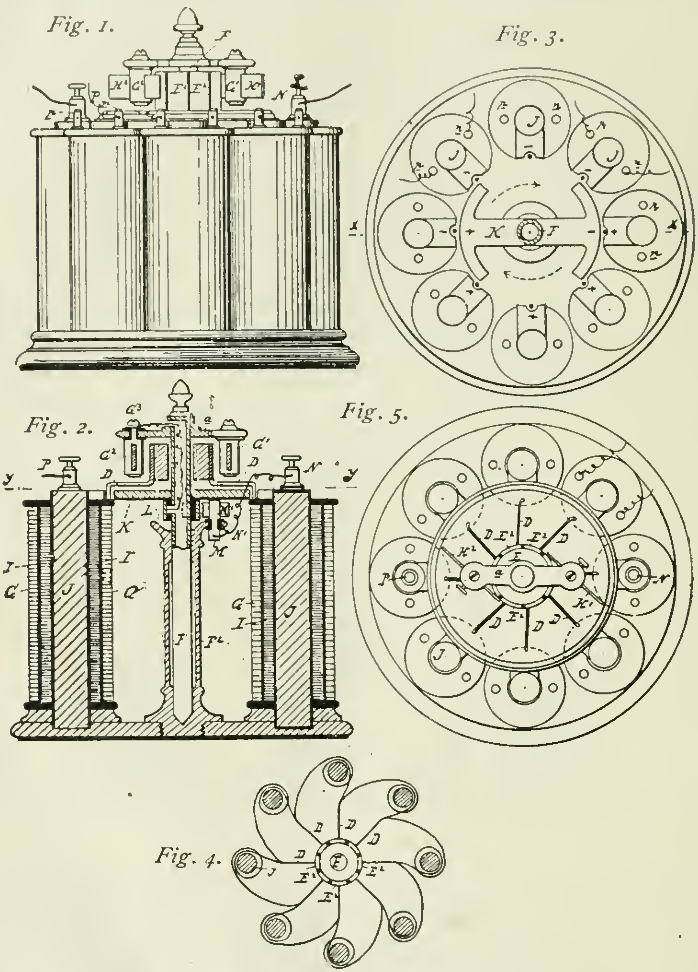

PLATE II.—Van Depoele's inductorium. 1882.

regularity in the secondary wave of electromotive force, and sparking at the brushes would here also seem to be a serious defect. This machine might be reversed, in which case it would run synchronously.

The next machine of the inductorium type to show itself belongs to the second subtype, where the additional advance is made of replacing the independent induction coils by a Gramme ring wound with the primary and secondary coils

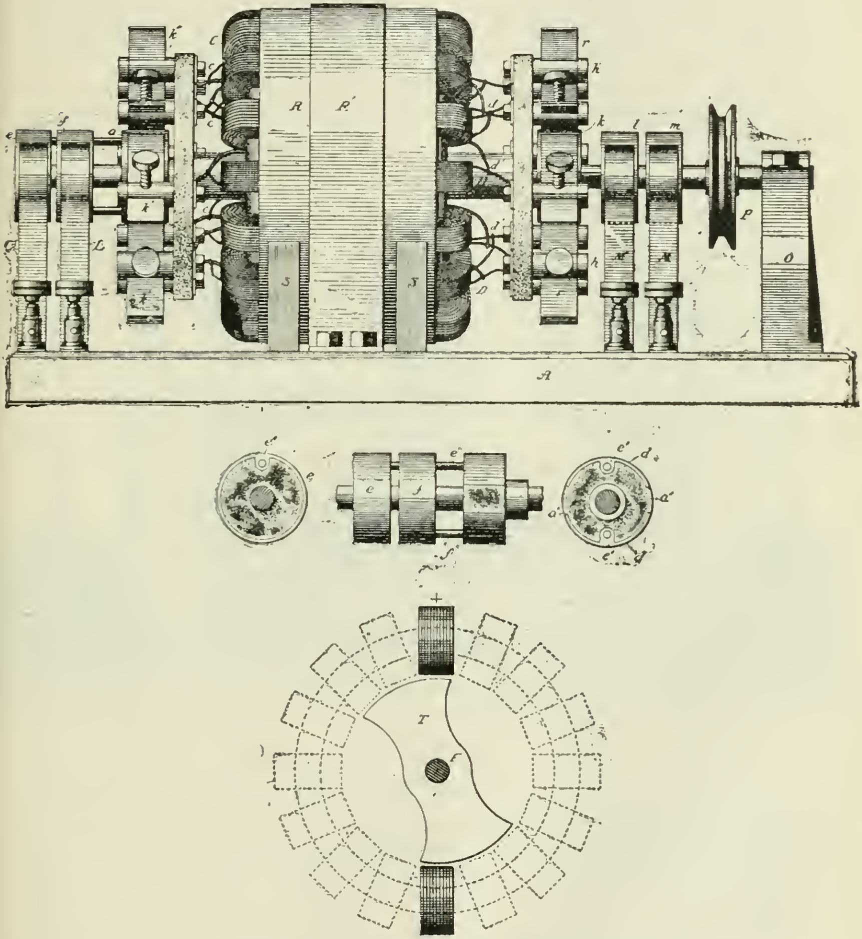

PLATE III.—Waterhouse's inductorium, with stationary ring. 1883.

placed in juxta- or superposition, and each connected to a separate commutator as in the dynamotor type. This is first shown in a patent to Waterhouse,[9] of 1883 (Plate III).

[9] No. 271,169, January 23, 1883.

The only rotating part in this machine is a spindle bearing a two-part commutator (*a*, *k*) and a pair of slip-rings (*e*, *f*; *l*, *m*) forming respectively the primary and secondary terminals, at each end; a separate brush bearing on the corresponding commutator is provided for each primary and secondary coil or segment wound upon the ring. A pulley *P* is shown for rotating the spindle, the speed of which is indifferent, so far as the ratio of transformation is concerned; or as an alternative, an internal magnet *T* (shown in the lower figure) may be used for the same purpose, as shown by

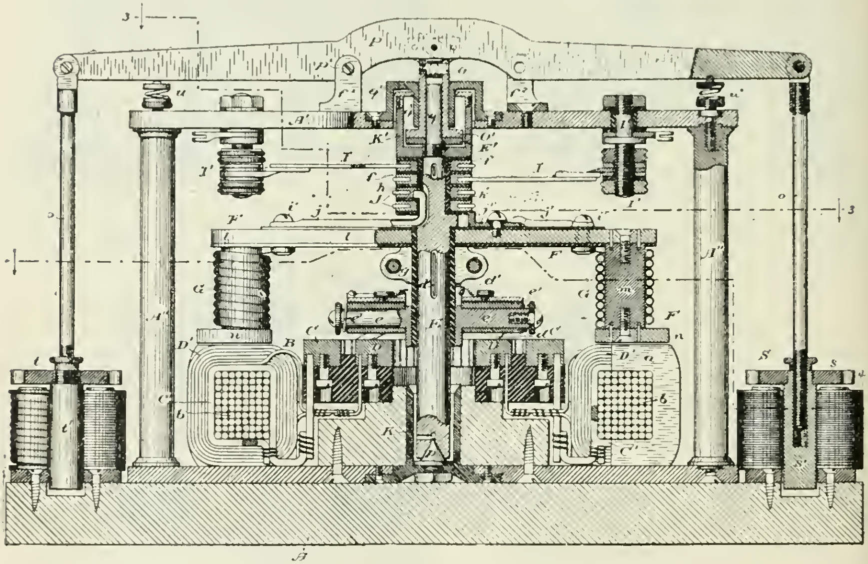

PLATE IV.—Main's inductorium, with stationary ring. 1887.

Van Depoele in Plate II. This machine is intended only for direct currents, and is, of course, completely reversible; we see in it a somewhat nearer approach to the dynamotor type.

In 1887 a patent was issued to Main,[10] which shows a device substantially identical with the foregoing in principle, though somewhat different in arrangement (Plate IV). The main difference lies in the essential part which is played by the magnetized bar—here called a "magnetic bridge"—

[10] No. 361,770, April 26, 1887.

which is employed to rotate the commutator brushes. This bar, *F*, is wound with coils, *G*, in the primary circuit and is made somewhat larger and placed at one side of the induction ring *C'*, which, with the commutators (*C*, *D*) and slip-rings (*f f*, *k k'*), are here shown in horizontal, and the shaft in vertical position. Now suppose this "magnetic bridge" made larger, so as to answer to a true dynamo-field to the ring *C'*, and make this ring rotate as an armature while the field thus formed remains fixed, and we have a true dynamotor. But the present machine, nevertheless, cannot be said to operate on the principle of a dynamotor; the "magnetic bridge" *F* is too insignificant to perform the regulating and magnetizing function of fields, or even to close the magnetic circuit induced in the stationary ring.

We now pass to the third subclass of the inductorium type of machines, wherein the ring is placed upon the shaft with and rotates with the commutator or commutators.

The first of these, from a patent to Gravier,[11] of 1883 (Plate V), shows two interesting transition forms which approach still closer to, without actually being of, the dynamotor type. The machine shown in the upper figures differs from that of the Waterhouse patent above described principally in the fact that the ring is made to rotate along with the two commutators to which it is attached, thus avoiding the slip-ring connection; and in addition, an external iron ring *K* is shown *to complete the magnetic circuit* which exists in all such machines and having two free magnetic poles formed at the diametrically opposite points of the ring where the current enters and leaves it. The patentee indicates that the reaction of these free poles upon the frame *K* "is or may be utilized to produce the rotation of the ring," but he does not appear to have thought the idea very practicable, as he adds a pulley *Z* for this purpose. In the machine shown in the lower figures the frame *K* is in the form of a ring surrounding the armature, which is stationary, and the machine otherwise substantially identical with the Waterhouse device.

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[11] No. 276,390, April 24, 1883.

A similar device was patented to Edison[12] in the same year. The principle of closing the magnetic circuit is a substantial improvement in this class of device, just as it was

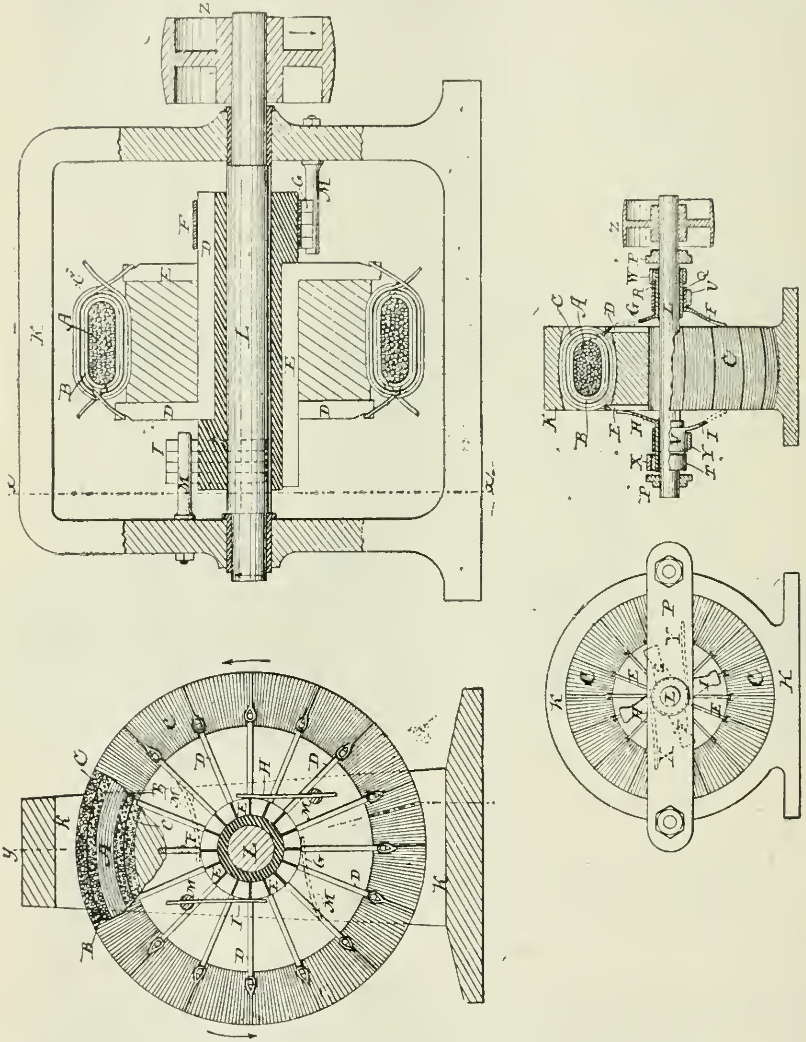

PLATE V.—Gravier's inductorium, with rotating ring. 1883.

in stationary transformers over the old Ruhmkorff coil. A still better way of accomplishing this is shown by Jehl,[13] in

[12] No. 278,418, May 29, 1883.

[13] No. 379,073, March 6, 1888.

a patent issued in 1888 (Plate VI). Here we have two Gramme rings in juxtaposition (*Fig. 2*); or one within the other (*Fig. 3*); or a ring surrounding a drum-wound core, as in *Fig. 5*. The primary is wound on one, the secondary on the other core, and the magnetic circuit is at all times completed by arranging the free poles of the two cores opposite each other, as indicated in the several figures. In *Figs. 2*

Fig. 1.

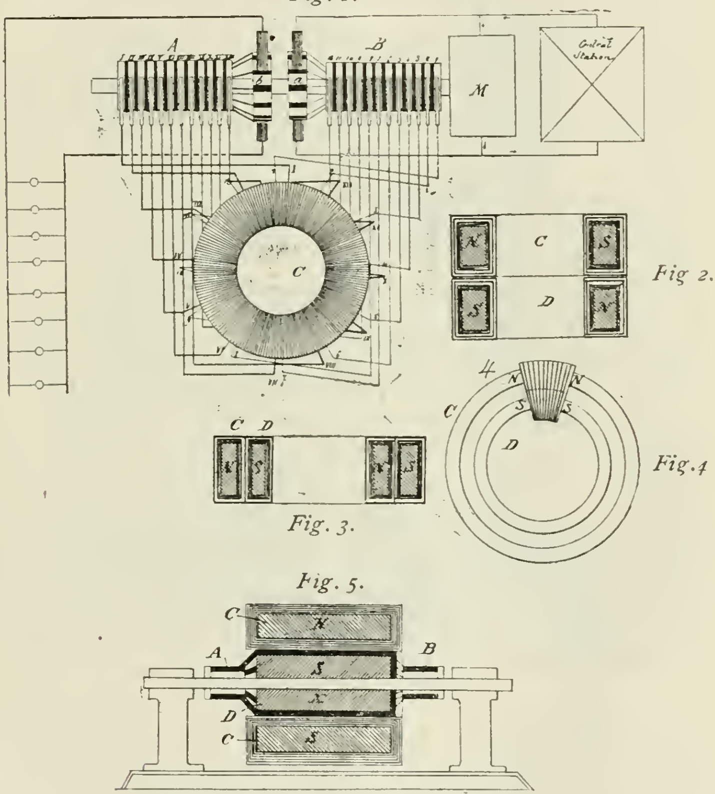

PLATE VI.—Jehl's inductorium. 1888.

and *3* the rings are stationary, and the individual coils are connected through slip-rings *A B*, to appropriate commutators *a b*, which are rotated by an independent source of power, as shown in *Fig. 1*; whereas in *Fig. 5* the induction rings are mounted on the shaft and rotated with their commutators. In neither case is there a suggestion of an ex-

ternal stationary field, nor would this here be a desirable addition. A slightly different form of this device is shown in a patent issued to Edison [14] as late as 1895; and it is claimed by the patentee that sparking is substantially suppressed by this arrangement, although the fact would seem somewhat doubtful. All of these machines are intended for use with continuous currents only.

We may here leave for the present the consideration of the inductorium type, and pass to the motor-generator and dynamotor types, with which, in its last described developments, it is closely connected; we shall, however, return to the inductorium later on when speaking of alternating currents, in consideration of some of the more recent devices, which have been evolved in a distinct direction. The devices of this class so far considered cannot be considered as anything more than milestones in the path of history, for, if they ever came into use, they are now practically obsolete. As just stated, all have been devised for the purpose of transforming pressure in continuous currents, alternating currents being only an incidental feature or possibility; and for the former purpose they have been superseded by the dynamotor. But the later machines, on the contrary, have a wholly different object in view, to wit, the rectification of polyphase currents, and here they appear to give great promise of success. Their more proper place for consideration, both from a historical and evolutionary standpoint, will be after the consideration of other and older devices for this purpose.

MOTOR-GENERATORS.

A motor driving a generator on the same shaft, as a means of obtaining a current of different pressure from the primary, would seem a simple device; it forms, however, the subject of a patent to Edison,[15] issued in 1881. In the patent the derived circuit serves to excite the field of the main generators, an arrangement now frequent in the case of alternating and polyphase generators.

This type of machine shades by various transition

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[14] No. 534,208, February 12, 1895.

[15] No. 251,550, of Dec. 27, 1881.

shapes into the dynamotor proper, as exemplified in Plates VII and VIII.

The lower figure of Plate VII is from a patent to Thomson,[16] issued in 1887. Here an open coil constant current armature *V* is shown driving one of the same type, *W*, which yields alternating currents at the slip-rings *r*.

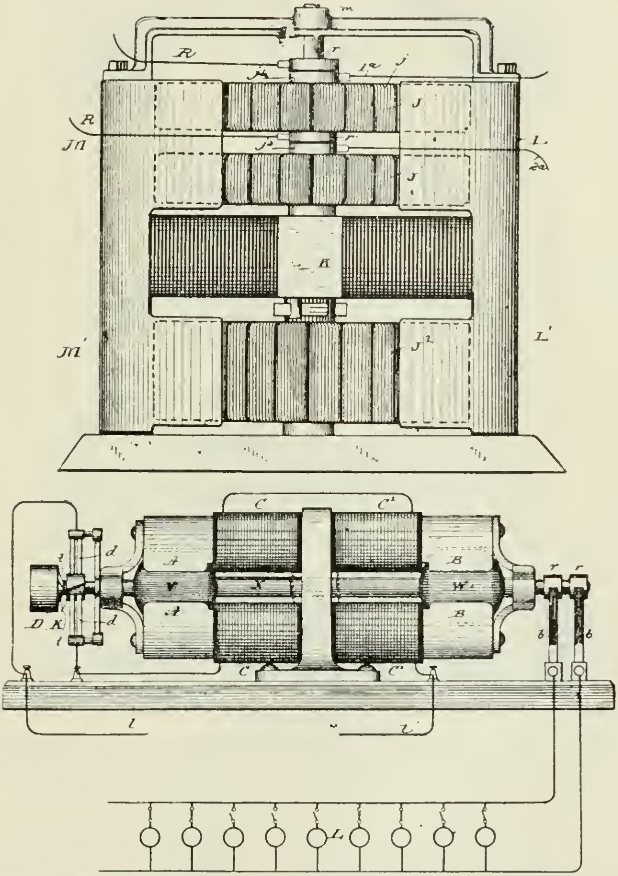

PLATE VII.—Motor-generators of Van Depoele (1889) and Thomson (1887).

The upper figure, from a Van Depoele[17] patent of 1889, shows a double secondary armature *J J′* adapted to produce two-phase currents.

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[16] No. 367,469, of Aug. 2, 1887.
[17] No. 417,654, of Dec. 17, 1889.

The figures of Plate VIII are from two patents issued to Henry[18] in 1894. The two armatures of the lower figure are directly connected by a piece of flexible shafting (3).

When two separate machines, a motor and a generator, are connected together so that the former drives the latter,

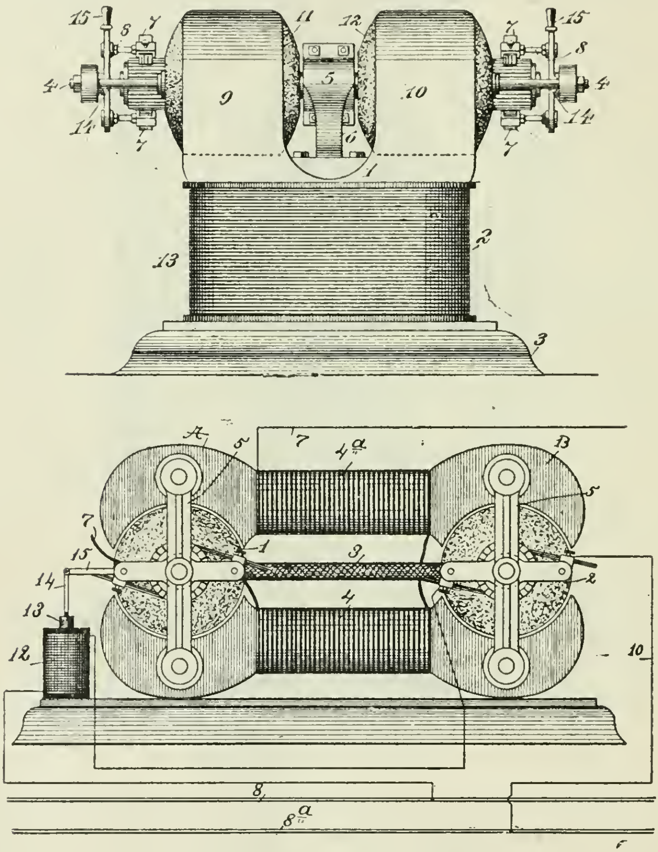


PLATE VIII.—Henry's motor-generators. 1894.

there is no inherent difficulty as to regulation; for each machine may be separately compounded, the one to yield a constant speed at constant pressure, the other *vice versa*, in the same way as if they were wholly independent. It is

[18] Nos. 512,820 of Jan. 16, 1894, and 524,852, of Aug. 21, 1894.

sometimes desirable, however, in such a case, to have all the regulation performed by one machine or by one circuit, which may be in this case either the primary or the secondary, this being chiefly a matter of preference, as the currents in both rise and fall together. Plate IX, which is from a

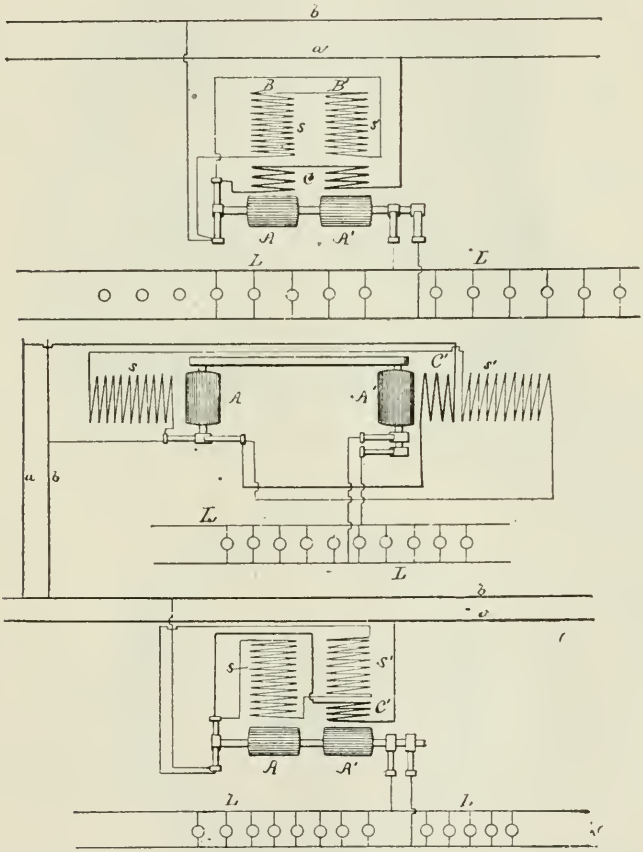


PLATE IX.—Rice's method of regulation for motor-generators. 1883.

patent to Rice[19] of 1883, shows three such couples, in each of which all the exciting current is taken from the primary circuit. In the upper couple, both fields are provided with compounding coils in series with the motor armature, one

[19] No. 495,229, of Apr. 11, 1883.

being arranged to decrease, the other to increase the field-strength in its respective field, according to well-known principles. In the lower couples, only the generator field is thus compounded.

DYNAMOTORS.

The proper signification of this word should be limited to machines for the pressure transformation of continuous currents. Machines involving a species transformation also merge into the rotary transformer proper, and in fact may be more properly termed "two-coil rotary transformers," and they will accordingly be considered further on under this head.

The very first machine of this type, in fact, has an alternating current secondary, and a four-phase secondary at that, although its author evidently had no idea of its possibilities; it is the invention of Van Depoele, forms the subject of a patent issued in 1882, and is shown in Plate XVI. But the secondary coil is not wound on the Gramme ring principle, and it is for this and the other reasons just mentioned best considered later on, as a two-coil transformer.

The first real dynamotor is again the invention of that remarkable pioneer, Van Depoele,[20] and is shown in Plate X. Here we have the machine of to-day in all its essentials, although of rather unusual form. The armature is horizontally placed, with the two commutators immediately above it; and it is embraced by a field-magnet extending beneath and diametrically across it. An alternative form (not here shown) is given, having a single armature replaced by two distinct cores for the primary and secondary respectively; and this would be nearly the equivalent of the motor-generator type as shown in the upper figure of Plate VIII. The patentee, however, styles this machine an *inductorium;* whence, as well as from his other patents of the latter class to which the machine bears a close resemblance, we are led to the inference that it is the latter which is the real ancestor of the dynamotor, and not the motor-generator, as might fairly be presumed to be the case from its somewhat more

[20] From his patent, No. 298,431, of May 13, 1884.

similar general appearance; while, at the same time, in its electrical properties also it is allied more nearly to the inductorium type.

The common continuous dynamotor is too simple and

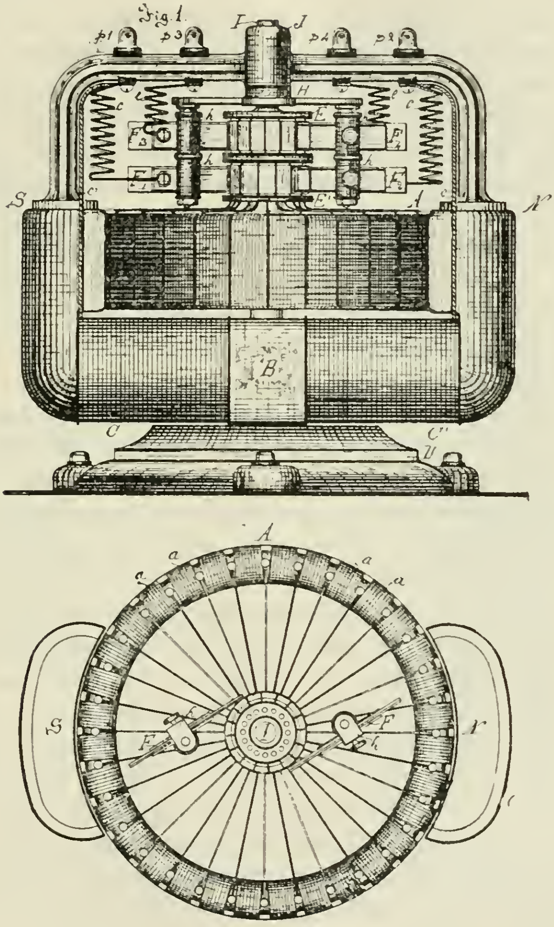


PLATE X.—Van Depoele's dynamotor. 1884.

well known a machine to require any special description; it has followed the same lines of improvement as other closed-coil dynamo-electrical machinery, and its improvements have been improvements in design rather than in the

introduction of any new principle. At the same time, however, it is a new machine, and possesses some peculiarities of its own, which will here be briefly touched upon.

The dynamotor is clearly distinguished from the inductorium on the one hand by the possession of strong and massive fields which play a principal part in controlling its motions, in the same way as in other dynamo-electric machinery; and, on the other hand, from the motor-generator in being intrinsically but one machine instead of two, so that its pressure relations are unalterably bound together.

Its most important feature, then, is this just mentioned, to wit, that the ratio of the primary and secondary pressures is wholly independent both of its speed and excitation, being the same, in fact (in the ordinary type, in which the amount of core-iron is the same for both windings), as the ratio of the two windings (with proper allowance for armature winding and core losses), just as in stationary transformers.

The next point to be noticed is that the armature reaction is practically *nil*, owing to the fact that the effects of the primary and secondary currents neutralize each other, the positive brush on one commutator being opposite the negative on the other. Both sets of brushes are therefore set at the neutral point.

The speed of a good dynamotor should vary but very slightly with load, being substantially the same as that of the same machine run as a *DC* motor on open secondary circuit. This speed is such as to allow just enough current to pass to overcome friction and armature losses. As the load comes on, the effects of the currents in the two coils neutralize each other, or nearly so, and the speed diminishes only just sufficiently to allow for the increased C^2R and core losses in the armature. This speed will, of course, be governed by the winding of the primary coil, the pressure used and the field strength, in the same way as in any motor. In the design of dynamotors, the considerations which govern the selection of speed relate to the proportion of iron and copper in the armature, corresponding precisely with frequency in the alternating-current transformer.

The question of regulation is the most important that in-

ventors and designers have been called on to meet in this machine. As changing the field-excitation can only produce an alteration in speed, without affecting the pressure relation, it is clear that where the magnetic circuits of the two coils are identical, we must look in another direction. In this case, supposing the primary to be supplied with current at a constant potential, whenever a large load is brought upon the secondary circuit there will be an undesirable drop in pressure at the secondary terminals of the machine, owing to the increased armature losses. Now, it is desirable not simply to compound the machine to compensate for this drop, but also to overcompound it to allow for line-drop, in the same manner as in the case of ordinary generators.

A device adapted to partly accomplish this end—though actually intended to maintain the adjustment of the brushes constant under varying load without sparking—is that shown in the upper left-hand figure of Plate XI.[21] As heretofore noted, the neutralization of the armature reactions by the two coils is not exact, due to the losses of conversion, which necessitate a proportionately increased motor current, and this uncompensated reaction increases with the load, causing some variation in the position of the neutral point, and consequent sparking. Now, by winding the *motor* coils over an additional length of armature core, not embraced by the generator coils, the counter-electromotive force is so increased as (the speed increasing in proportion) to increase the generator E.M.F. and current sufficiently to compensate for the drop, and at the same time bring the armature reactions of the two coils to exact equality.

The equality will be maintained at all loads, as the additional power gained is proportional to the primary current, and it is evident that a similar effect would be produced upon the pressure regulation, although imperfectly. In the other figures of the same plate,[22] however, we see a true pressure regulator, in which either or both of the two coils are provided with separate supplementary cores and inde-

[21] From a patent to Walter, No. 351,544, of October 26, 1886.

[22] From a patent to Thomson, No. 459,423, of September 15, 1891.

pendent series-wound field magnets acting upon each core. In the lower figure on the right, it is the motor-coil which has a series-wound field; on the left, the generator or secondary coil; and in the upper right-hand figure, each has a separate supplementary field.

Another method, which may be considered the electrical equivalent of the foregoing, is to arrange a small booster,

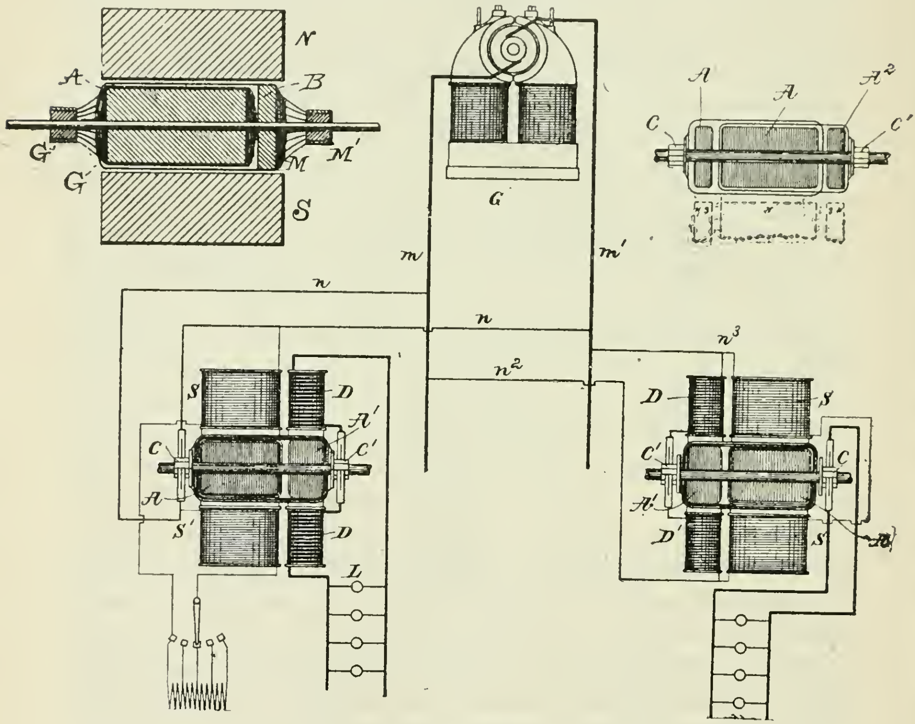


PLATE XI.—Compound dynamotors of Walter (1886) and Thomson (1891).

or series-wound dynamo in series with the secondary coil on the same shaft. A variation of this is shown in a patent to Burke,[23] issued in 1894, the booster being in series with the *motor* or primary coils, and excited by shunt primary and series secondary field windings, so as to increase the speed of the machine as the load increases. There are, however, serious practical objections to such a plan, for, as is

[23] No. 524,376, of August 19, 1894.

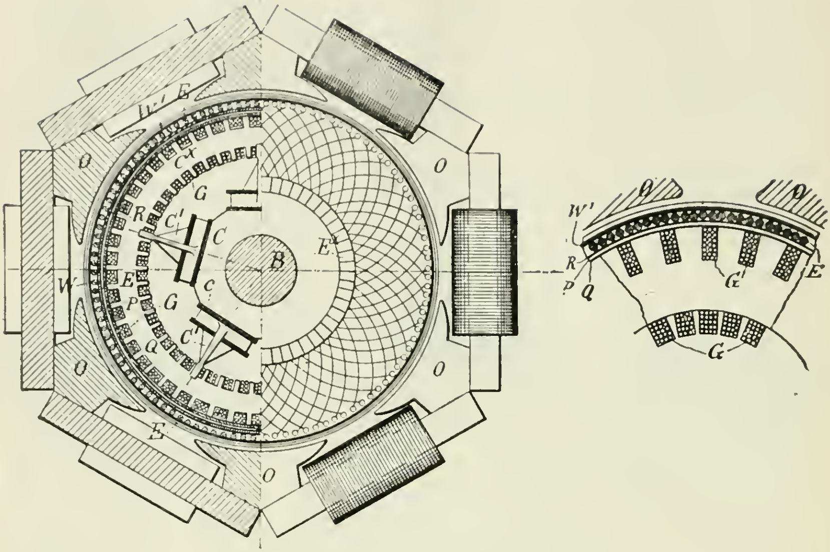
well known, such booster machines, which have to carry a very large current at a low pressure, are both costly and inefficient, and by thus introducing a second machine we lose all the advantage we gained from the consolidation of the motor-generator into *one* machine, introduce additional complexity, and at the same time do not regain the independence and flexibility of the motor-generator system. Moreover, as the dynamotor, besides supplying current, has to furnish the necessary power to drive the booster, the armature reactions are no longer balanced; and a larger machine must be used for this additional power.

Of armature-windings not much need be said, the main object to be kept in view being, here as in stationary transformer windings, the avoidance of magnetic leakage between the two circuits. The windings may be either side by side in alternate strips, or one over the other; the latter of which is deemed preferable in most cases, especially where toothed armatures are employed; but the presence of a high pressure coil may dictate a less desirable arrangement.

There is one species of dynamotor which deserves a special notice, which is that adapted to mediate between constant pressure and constant current circuits. All the machines so far treated of are intended only for constant pressure working, and are not fitted to perform this function, although it seems not unlikely they might be used to satisfaction between two constant current circuits—if such a case ever occurred in practice. The practical utility of a machine for the service just mentioned, however, arises wherever, for instance, we wish to obtain an incandescent-lamp from an arc-lamp circuit, or the reverse. In particular, it has been proposed[24] to operate scattered lighting circuits by individual motor-generators whose primaries are connected in series on a constant current circuit. An example of a dynamotor for this service is shown in the upper figures of Plate XII, which are taken from a patent to Thury.[25] This machine is constructed on somewhat the

[24] *Electrician* (London), V. 24, p. 112.

[25] No. 567,424, of Sept. 8, 1896.



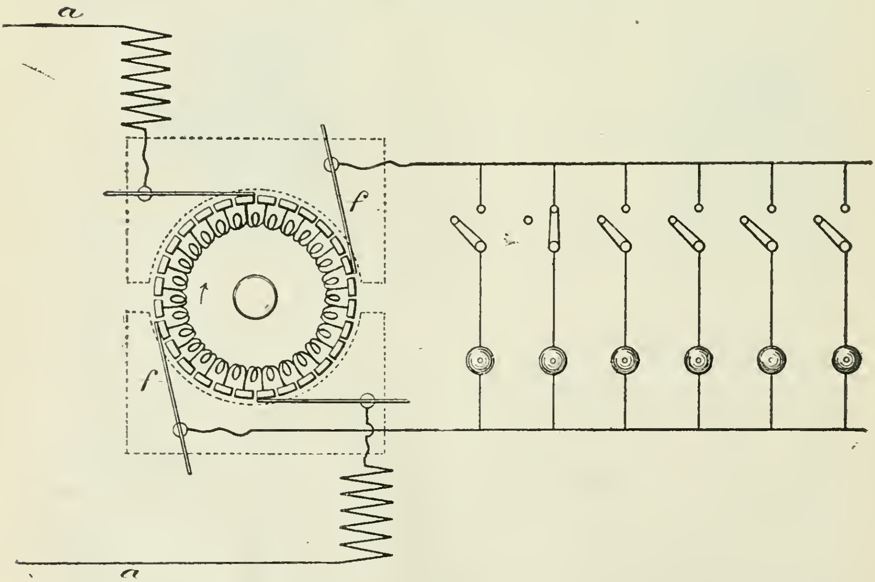


PLATE XII.—Constant-current to constant-pressure transformation.
1. Thury's method. 2. Scribner's method. 1896.

same principle as the constant-current stationary transformer—to wit, of large inductance and magnetic leakage between the primary and secondary circuits. The figure shows a six-pole machine having a ring armature core C^x, toothed on both its exterior and interior circumferences. In these grooves are wound, Gramme fashion, the coils *G* intended for connection with the constant current circuit. Over these is placed circumferentially a layer of insulation *Q*, over this a magnetic shield consisting of a layer of iron wires *P*, then another layer of insulation *R*, and finally the constant pressure coils *E* drum-wound over the insulation *R*. The large leakage and self-induction of the constant current coil enables the brushes to be shifted over the commutator without causing sparking, so as to be adjusted to the proper pressure called for by the load on the machine, which shifting is done automatically by means of a fly-ball or solenoid governor.

Another interesting machine for this purpose is that shown in the lower figure of the same plate, from a patent to Scribner.[26] This belongs perhaps more strictly to the rotary transformer than to the dynamotor class, as it has an armature of only one coil. It has two pairs of brushes, one, the generator or constant-pressure pair *f*, being fixed in the usual position on the commutator. The other, or primary pair, supply constant current to drive the machine, normally have a certain lead over the secondary pair, and are shifted automatically by a solenoid governor back and forth upon the commutator to keep the current constant, and in accordance with the voltage demanded to maintain the proper speed. When moved back, the current in the secondary circuit is increased, but is limited to that of the primary. The armature is thus divided into four portions, in two of which the current is greater and in two less than half the primary current, leading to armature reactions of a varying character, so that it would seem doubtful if the objection of excessive sparking could be successfully overcome.

Among "freak" machines we may mention one in pass-

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[26] No. 574,278, of Dec. 29, 1896.

ing, described by Dieckmann[27] in a patent of 1894, and shown in Plate XIII. This machine shows a three-ring armature, the outer rings of which, *D d*, are wound with primary, and the central ring *F* with secondary coils. This central ring is composed of *non*-magnetic material, as wood. A double set of field-magnets *B B* is provided, one for each primary, and each set being wholly independent of the other. The magnetic circuit of the primary rings would

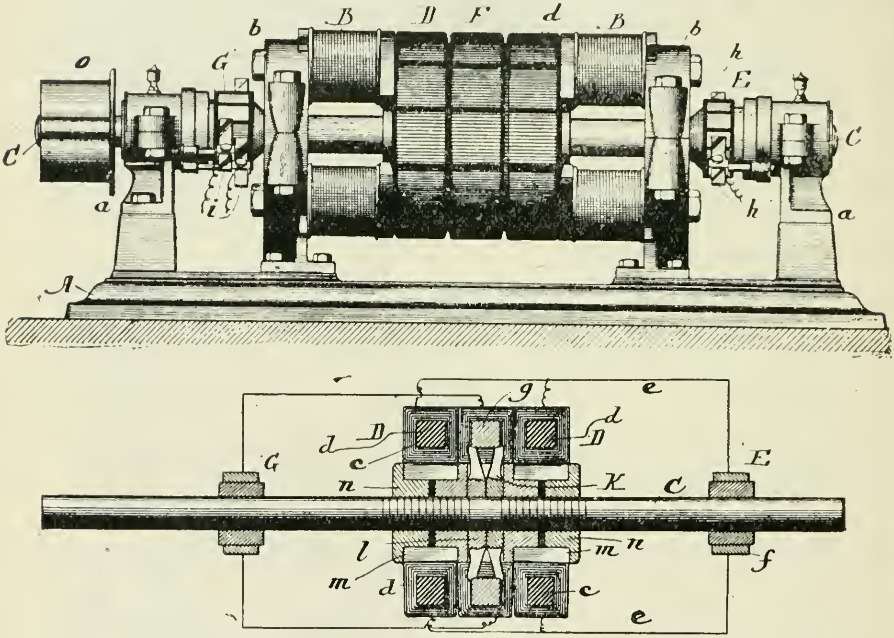

PLATE XIII.—Dieckmann's dynamotor. 1894.

appear to be largely completed through the field magnets *B*, but a portion of the induced field must pass through the secondary armature ring *F*. This ring is removed from the magnetic field created by the pole-pieces, and inductively influenced by the successive changes of direction of the current in the juxtaposed primary coils. The brushes on the secondary commutator are separated by only one commutator segment, and unidirectional impulses are thus

[27] No. 513,459, of Jan. 23, 1894.

transmitted to a lamp-circuit; there being a pair of such brushes opposite each pole-piece *B*, connected to as many secondary circuits. For equal primary and secondary windings, the primary volts of this machine would appear to bear a very high ratio to the secondary.

[*To be continued.*]

BOOK NOTICES.

A Hand-Book of Industrial Organic Chemistry. By Samuel P. Sadtler, Ph.D., F.C.S., Professor of Chemistry in the Philadelphia College of Pharmacy. Third edition, revised. 8vo, 529 pages and index. Philadelphia: J. B. Lippincott Company. 1900.

The third edition of this well-known and useful work finds it much enlarged. The rapidity with which all departments of chemistry, and especially applied organic chemistry, develop, makes very laborious the task of keeping such a book up to date. The author has done this duty well, and the present edition will maintain and extend the popularity of the work. We note from the preface that the most extended revision has been in the section devoted to dye-stuffs, among which are to be noted the tables for the identification of commercial colors. Such systematic methods are very useful to the practicing analyst who encounters often the problem of determining the nature of colors used in foods and beverages.

The elaborate bibliography appended to each section will be of great assistance to the practical analyst. The abundant statistical information will be interesting to many.

The work is well written and well printed. The illustrations are numerous and satisfactory, and there is a good index. H. L.

Commercial Organic Analysis. By Alfred H. Allen, F.I.C., F.C.S. Third edition. Rewritten and enlarged; revised and edited by J. Merritt Matthews, Ph.D., Professor of Chemistry and Dyeing in the Philadelphia Textile School. 8vo, 573 pages and index. Philadelphia: P. Blakiston's Son & Co., 1900.

The issue of this volume has been awaited for some time with much anxiety, for the earlier editions are out of print and the topics covered by them are of great importance to chemists. The chapter on aromatic acids, which formed the first sixty pages or so in the second edition, has been transferred to the third part of Vol. II (in preparation), and the present work opens with a chapter on tannins. Dr. Matthews has added much new material, especially, as might be expected, in the fast-growing department of artificial colors. A modern classification of these has been introduced and the details of descriptions have been condensed and made more rapidly available by the extensive use of tabulation. About eighty pages are devoted to the tannins, all the recognized methods of analysis having been included, but

the reviser expresses regret that the department of analysis is still in an unsatisfactory state.

The reviser's practical experience with color work ensures the trustworthiness of the section on colors. A glance at the index shows the great number of those now known. Rational formulæ are usually given. A short chapter on the chemical character of writing inks will be found interesting and valuable. We regret that Dr. Matthews has adopted the plan of giving journal references by the volume instead of by the year. The latter method seems more simple and direct. The index is extensive and creditable. H. L.

Machinists' and Draughtsmen's Hand-Book. By Peder Lobben, Mechanical Engineer, etc. New York: D. Van Nostrand Co. 1900. 8vo, pp. 438. (Price, $2.50.)

The author has designed this book to serve the needs of the great body of working mechanics and draughtsmen. It contains a large collection of tables, rules and formulæ covering a great variety of subjects. Many examples are given explaining the application of the rules and formulæ. It should prove useful to the class for which it is intended, not only as a handy reference book, but also as a text-book, from the study of which the reader may familiarize himself with the principles of elementary mathematics and mechanics. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, February 20, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1901.

MR. A. E. OUTERBRIDGE, JR., in the chair.

Present, 107 members and visitors.

Additions to membership since last report, 32.

Prof. M. I. Pupin, of Columbia University, New York, presented an address on "Electrical Wave Propagation," elucidating the principles involved in the study of these phenomena, with special reference to their application in his recent inventions in the field of long-distance telephony. The speaker illustrated his address with the aid of mechanical devices, exhibiting various modifications of wave transmission.

The subject was freely discussed. The paper and discussion thereon have been reserved for publication.

A vote of thanks was given the speaker for the interesting and very lucid manner in which he had treated his theme.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, January 2, 1901. Concluded.*]

The following reports were adopted :

(No. 2154.) *Improvement in Light-Projecting Glass.*—American Prismatic Light Co., Philadelphia.

ABSTRACT.—The light-projecting glass referred to in this application is protected by letters-patent of the United States No. 637,145, November 14, 1899, granted to George Moffat and Edward J. Dobbins, of Philadelphia.

The object of the improvement is to increase the amount of light that passes into a room and to secure equal distribution of same by diffusion. The glass used in this system is formed of parallel lens bars on one side, and parallel prism bars placed at right angles to the lens bars, on the other side.

The function of the external lens-bars is to refract the light in a horizontal direction and especially to make use of lateral rays that strike at so great an angle that they would be almost entirely reflected from a plane surface. The form of these lenses is such that there is no internal reflection from the inner surfaces of the prisms, thus securing the emission of all rays that strike these surfaces.

The function of the internal prism forms is to refract the light in a vertical direction, which, combined with the horizontal refraction of the external lenses, produces nearly uniform distribution in the room.

The forms of the prism faces vary to suit the requirements of distribution, and the angle from which the incident light comes. In extreme cases, where the light comes from a great elevation, as from the exposed sky over the top of a building or the like, the glass is set in a frame that is hinged from the top, and thus can be adjusted at any angle.

The investigators find that the combination of prisms on one side and lens bars at right angles on the other increases the strength of the glass and permits of panels of larger size being used. Also, the cylindrical form of the outer surface (placed vertically) renders it easy to clean the glass.

The report concludes : "On account of the special combination of scientific principles involved, and the excellent results obtained in places where this glass has been applied," the award of the John Scott Legacy Medal and Premium is recommended to the inventors. [*Sub-Committee.*—George A. Hoadley, Chairman ; Geo. F. Stradling, Samuel Sartain, F. E. Ives.]

(No. 2163.) *Reaction Breakwater.*—Lewis M. Haupt, Philadelphia. The Elliott Cresson award is made. Report is reserved for publication in full. [*Sub-Committee.*—Ambrose E. Lehmann, Chairman; L. E. Levy, John Haug.]

The following passed first reading :

(No. 2141.) *General Electric Co.'s Constant Current Arc-Light Transformer.*

(No. 2162.) *Improvement in Gate Valves.*—Henry J. Schmitt.

[*Abstract of proceedings of the stated meeting of February 6, 1901.*]

The following reports were adopted:

(No. 2141.) *General Electric Company's Constant Current Transformer.*—General Electric Company, Schenectady, N. Y.

This report is reserved for full publication. The John Scott Legacy Medal and Premium is recommended to Elihu Thomson, the inventor. [*Sub-Committee.*—Francis Head, Chairman; Geo. A. Hoadley, T. Carpenter Smith.]

(No. 2162.) *Improvement in Gate Valves.*—Henry J. Schmitt.

ABSTRACT.—This invention is the subject of letters-patent of the United States No. 604,592, May 24, 1898, issued to applicant.

The valve consists of a carrier or cage which is moved by the thread on the spindle, or by a vertical movement of the spiudles. The carrier is guided by a side projection which travels in a groove on the body of the valve. This carrier holds the valve disks, which are of brass, each having two lugs which project within the carrier and bear against the top and bottom, so causing them to move with the carrier. The projecting lugs are of such length that they bear against the disk on the opposite side, and, being rounded, permit the disks to make a good joint on one side, even if there be scale under the other. These disks are entirely free to move in a horizontal direction relative to the carrier, or to rock one over the other to allow the disk to conform to the plane of the seat. Vertically the disks must move with the carrier, and the first movement frees the valve on one side, but as long as there is a higher pressure on one side than on the others, one of the disks will be forced against the seat. This friction will be present in all classes of gate valves in some form or other.

The report concludes as follows:

"This valve is a marked improvement on the old form of Nelson valve, in that it is simpler and cheaper, and appears to be more effective. The Edward Longstreth Medal of Merit is awarded to the inventor." [*Sub-Committee.*—Arthur M. Greene, Jr., Chairman; J. Y. McConnell, Henry F. Colvin, Frank P. Brown, Chas. Day.]

First reading:

(No. 2140.) *Pneumatic Clock.*—A. L. Hahl, Chicago.

(No. 2160.) *Rivett-Dock Thread Tool.*—Herman Dock, Philadelphia.

(No. 2168.) *Bardwell Votometer.*—The Bardwell Votometer Company, New York.

(Nos. 2108, 2121, 2126.) *Various Grate Bar Inventions.*—Dismissed for want of data.

W. H. W.,
Secretary.

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, January 24th. Dr. W. J. Williams in the chair.

Present, 45 members and visitors.

The following officers were elected to serve for the year 1901, viz.:

President—Dr. W. J. Williams.

Vice-Presidents—Lyman F. Kebler and Joseph Richards.

Secretary—W. E. Ridenour.

Conservator—Dr. Wahl.

Dr. Williams presented, as the annual address of the President, a paper entitled "A Brief Sketch of the Essential Requisites of Powder as Distinguished from Explosives." The paper was illustrated by the exhibition of an instructive series of specimens. The paper was referred for publication.

Mr. Lyman F. Kebler made a communication on "Walnut Oil." He had found on examination that numerous commercial products sold under this name were sophisticated. One specimen examined, for example, proved to be nothing else than glycerine flavored with certain essential oils, and quite unfit for the uses for which the genuine oil is so highly valued (*i. e.*, its eminent drying quality). Other commercial samples were found to be equally sophisticated. A specimen of the genuine oil, expressed from the kernel of the black walnut, was shown, and its drying quality was demonstrated by the exhibition of several samples of rubber-like oxidized films of the oil that had been spread upon glass.

Dr. H. F. Keller, Dr. R. H. Bradbury and Dr. S. P. Sadtler followed with a series of chemical lecture experiments, all of which were interesting and many novel.

A vote of thanks was passed to the contributors of the evening and the meeting adjourned.

W. E. RIDENOUR,
Secretary.

PHYSICAL SECTION.—*Stated Meeting*, Wednesday, January 23d, 8 P.M. Dr. A. E. Kennelly in the chair.

Present, 18 members.

The following officers were elected to serve for the year 1901:

President—Dr. Geo. F. Stradling.

Vice-Presidents—Prof. Luigi D'Auria, Prof. Edward A. Partridge.

Secretary—Jesse Pawling, Jr.

Conservator—Dr. Wahl.

Dr. Kennelly delivered the address of the retiring President, choosing for his theme "Some of the Present Aspects of Physical Science." At the conclusion of his remarks he alluded to the urgent need in the United States of a national bureau for the standardization of instruments of precision, such as those at the Kew Observatory, in England, and at Berlin in Germany. He alluded to the fact that there was at present pending before Congress a bill providing for the establishment of a bureau of this character, and urged that the Section should signify its approval of the measure. On Mr. Bradbury's motion, the Section signified its approval of the pending bill to establish a bureau of weights and measures, and urged its speedy passage. Dr. George F. Stradling presented a communication on "Recent Investigations of the Physics of Water," giving a *résumé* of a number of recent investigations of the subject which go far towards explaining a number of the anomalous physical properties of water. W.

Section of Photography and Microscopy.—*Stated Meeting*, held Thursday, February 7, 1901. Dr. Chas. F. Himes in the chair. Present, 28 members and visitors.

An amendment to the by-laws was adopted, providing for an Executive Committee to take general charge of the affairs of the Section. The President appointed as members of this committee, Dr. Henry Leffmann, Chairman, and Messrs. W. N. Jennings, F. E. Ives and John G. Baker.

Dr. Himes made some remarks on the permanency of photographic plates and papers, and in illustration of his remarks showed pictures made from plates that had been kept for sixteen years before exposure.

Dr. Leffmann contributed some observations on the "Effect of Light on Chemicals, especially Mercurous Compounds."

Mr. E. Wager Smith, of Philadelphia, exhibited and explained a new and ingenious "Exposure Slide."

The President announced that at the March meeting of the Section the subject of "Photographic Record Work" would be taken up.

F. M. Sawyer,
Secretary.

Mining and Metallurgical Section.—*Stated Meeting*, held Wednesday, February 13, 1901. Prof. F. L. Garrison in the chair. Present, 17 members and visitors.

Mr. Joseph Richards gave the concluding portion of his address on the "Utilization of the Wastes from the Use of the White Metals." This was devoted especially to the recovery of the wastes from the stereotyping, electrotyping, type manufacturing and other industries in which solders, type metal, stereotype metal, pewter, britannia and other white alloys were used. The speaker exhibited samples of the wastes and the useful products obtained from them.

Mr. Richards exhibited a balance of his invention devised for the purpose of quickly ascertaining the proportion of tin in by-products containing this metal alloyed with lead and with antimony.

The paper is reserved for publication.

Mr. Caspar Wistar Haines read a communication on the "Earthquake of Colima, January 19, 1900," which was illustrated by a number of lantern views of the region adjacent to the volcano of Colima which was affected by the earthquake, and views of the buildings destroyed and injured. Reserved for publication.

Adjourned.

G. H. Clamer,
Secretary.

Mechanical and Engineering Section.—*Stated Meeting*, held Thursday, February 14th. Mr. John F. Rowland, Jr., in the chair. Present, 26 members and visitors.

The paper of the evening was read by Mr. Oberlin Smith, Bridgeton, N. J. The subject was "The Jig Habit in America." The speaker treated of jigs and their uses. The subject was discussed by Mr. Falkenau and others.

The paper is referred for publication in full.

Daniel Eppelsheimer, Jr.,
Secretary.

JOURNAL

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VOL. CLI, NO. 4. 76TH YEAR. APRIL, 1901

ANTARCTICA: A HISTORY OF ANTARCTIC DISCOVERY.*

BY EDWIN SWIFT BALCH.

INTRODUCTION.

After lying dormant for nearly half a century, interest in the Antarctic has at last reawakened, and several expeditions are now fitting out for South Polar research. While looking forward hopefully, therefore, to an increase of knowledge, it is also necessary to look backward and review the results already accomplished. For not long since Sir Clements R. Markham, P.R.G.S., proposed in the *Geographical Journal*, for November, 1899, to divide the Antarctic into four quadrants, each covering 90° of longitude, and to bear English names. The advantages of this proposition on the score of convenience are not self-evident. Moreover, it is only just to remember that, besides Englishmen, mariners of many other nations have made discoveries in the Antarctic. A letter that I wrote on this matter was

published in the *Nation*, New York, May 10, 1900, and also in the *Evening Post*, New York, of the same date. Up to that time I had made no special study of Antarctic geography, and discovered then how difficult it was to find accurate data. This monograph may be considered as an amplification of the letter, and I trust that the references in it, at least, will help other geographers to investigate the subject and bring out the whole truth.

Americans ought to take an interest in the Antarctic, for American explorers have done good work there. Not only were Sheffield, Fanning, Palmer, Pendleton, Johnson, Morrell and Smiley among the first to follow and make new discoveries in the tracks of the Hollander, Dirk Gerritz, but also it was an American, Charles Wilkes, of the United States Navy, who first announced, on March 11 and 13, 1840, that there is a mass of land, continental in dimensions, in Antarctica. It is the only discovery of the kind since that of Australia, and, in the writer's opinion, it places Wilkes at the head of American explorers.

A number of gentlemen have helped me in one way or another in this work. I am especially indebted to Dr. Frederick A. Cook, of Brooklyn; Prof. George Davidson, of San Francisco; Mr. George C. Hurlbut, of New York; Mr. P. Lee Phillips and Captain C. C. Todd, U.S.N., of Washington, D. C.; and Mr. Henry G. Bryant, Mr. F. L. Garrison, Prof. Angelo Heilprin, Mr. Edward S. Miles, Mr. Bunford Samuel, Dr. William H. Wahl and Mr. Harvey M. Watts, of Philadelphia.

I. VOYAGES LEADING FROM A BELIEF TO A DISBELIEF IN A TERRA AUSTRALIS INCOGNITA.

That some great land existed near the South Pole seems to have been guessed at centuries ago. Ptolemy is accredited with having held and expressed some such idea. It is hard to see on what the belief rested, but it lasted until Captain Cook's second voyage. Amerigo Vespucci may have unintentionally helped to foster the notion. In his letter to Pier Soderini, Gonfalonier of the Republic of Florence, he narrates in his third voyage* that his ship reached

* "The First Four Voyages of Amerigo Vespucci," London, Bernard Quaritch, 1893, page 39.

52° south latitude, and that they sighted a new and rough coast, along which they sailed for twenty leagues. Varnhagen* has shown that this land is almost surely South Georgia, and Vespucci, therefore, has perhaps some claim to be looked on as the first discoverer of land in Antarctica.† However this may be, on many maps of the sixteenth century there is a *Terra Australis Nondum Cognita* or Great Southern Continent marked as stretching from Tierra del Fuego to Australia. In the map of Orontius Fine, made in 1531, and published in the Paris *Grynaeus* of 1532, there is charted a *Terra Australis recenter inventa, sed nondū plenè cognita;* and in the Mercator map of 1538, this land is also shown and inscribed as a certainty.‡ The voyages of the pilot, Juan Fernandez, who, in about 1563, certainly reached the island which bears his name, and who, in about 1576, may have reached the coast of New Zealand, helped to strengthen the belief, as he was accredited with having touched this unknown continent.§

The first positive discovery of land in Antarctica appears to have been made accidentally by a Dutchman, Dirk Gerritz,

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* Varnhagen, F. A. de: "Amerigo Vespucci, son Caractère, ses Ecrits," etc., Lima, 1865, page 111.

† I am not sure who first applied the name Antarctica to the South Polar regions; it may have been Sir John Murray. In this monograph I use the term to denote the portion of the earth round the South Pole, including land, islands, ice and ocean. Geographers are not yet agreed as to the limits of the Antarctic. It is an open question whether South Georgia and Bouvet and Kerguelen Islands belong to it. Undoubtedly, however, it includes everything south of 60° south latitude; although, perhaps, no hard-and-fast line can be drawn. Of no part of the world is so little known as about the Antarctic, and about none has there been so little interest taken. This is probably partly due to its distance from the centers of thought, and partly also to its lack of life, both of animals and men. The human interest is entirely absent in the desolate wastes of the South Pole, and not the least curious fact connected with them is that there is no apparent record of any woman having passed beyond 60° south latitude.

‡ These two maps are reproduced in "The Continent of America," by John Boyd Thacher. New York: W. E. Benjamin, 1896.

§ Burney, James, Captain in the Royal Navy: "A Chronological History of the Voyages and Discoveries in the South Sea or Pacific Ocean," London, Vol. I, 1803, pages 274, 300–303.

at the end of the year 1599.* He was a member of a squadron of five ships which sailed in 1598 for the West Indies. The names of the ships, in German, as shown by an engraving on the title page of de Bry, were: "Hoffnung," "Glaube," "Liebe," "Trewe," "Frohlich Botschaft." The commanders of the fleet were: "Hoffnung," Admiral Jacob Mahu; pilot, William Adams; "Liebe," Vice-Admiral Simon de Cordes; "Glaube," G. van Benningen; "Trewe," J. van Bockholt; and "Frohlich Botschaft," Sebald de Weert. According to Burney, the "Hoffnung" and the "Liebe" eventually reached Japan, and the pilot, William Adams, was ordered by the Emperor to come to Osaca. He did so and the Emperor never would let him depart, and, after marrying a Japanese wife, Adams lived the remainder of his days in Japan.

Gerritz is mentioned several times in de Bry's narrative, in which his name is spelled Dirrick Gerritsz, and also Dierick Geeritsz. The account is in Latin, and is said to be a translation of the journal written in German by Ber-

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* Bry, Theodori de: "Americae. Nona & Postrema pars." Francof. Apud. Matth. Beckerum. 1602. The account of the expedition is a separate part of the book under the following title: "Vera et accurata descriptio eorum omnium, quae acciderunt quinque navibus Anno 1598, Amstredami expeditis & per fretum Magellanicum ad Moluccanas insulas perrecturis: naui praecipue Fidei, Capitano de VVeert addicta qui post infinitos labores & aerumnas biennio integro tolerates, tandem anno 1600. re infecta ad suos rediit."

Herrera, Antoine de: "Description des Indes Occidentales, qu'on appelle aujourdhuy le Nouveau Monde," par Antoine de Herrera, Grand Chroniqueur des Indes et Chroniqueur de Castille, Translatée d'Espagnol en Francais. A Amsterdam, chez Michel Colin, Anno MDCXXII. In this is "Recueil des Navigations de l'Estroit de Magellan," pages 179–195. in which is: "Voyages de cinq bateaux de Jaques Mahu et Simon de Cordes, qui partirent de Rotterdam, l'an 1598, pour l'Estroit de Magellan," pages 189–193.

Herrera, Antonio de: "Novus Orbis, Sive Descriptio Indiæ Occidentalis." Amstelodami, Apud Michaelem Bibliopolam, MDCXXII.

Brosses, Charles de: "Histoire des Navigations aux Terres Australes." A Paris, chez Durand, MDCCLVI. This includes the voyage of "Simon de Cordes et Sebald de Weert." "En Magellanique." Tome Premier, pages 274–294.

Burney: "A Chronological History," etc. London, 1806. In Part II, Chapter XII, pages 186–204, is "Voyage of Five Ships of Rotterdam, under the command of Jacob Mahu and Simon de Cordes, to the South Sea."

nard Jansz, surgeon of the expedition. No mention appears to be made by de Bry of antarctic discoveries, which may be accounted for by the fact that the author of the narrative was on one of the other ships, and that the narrative was published probably before news of Gerritz's discovery reached Europe.

The fleet sailed from Goree Harbor, Holland, on the 27th of June, 1598. The General or Admiral, Jaques Mahu, died on the 24th or 27th of September. This caused some changes among the commanders. Sebald de Weert became commander of the "Glaube," and Dirk Gerritz commander of the "Blyde Boodshap." The fleet entered the Strait of "Magalhaens"* on April 6, 1599, and spent most of the winter in *la Baye Verte*† or Cordes Bay,‡ "where they were miserably lodged."§ On the 2d of September the ships reached the South Sea, and on the 8th or the 10th or the 15th of September, either on account of fog,|| on account of a furious storm,¶ or through some mistake in signalling,** the ships parted company.

Of the subsequent adventures of Gerritz, Herrera says, in 1622:†† "La Fuste de Diric Gherrits qui s'estoit esgaree le 15 Septembre des autres, scavoir de VVeert & Cordes, fut portee par la tempeste jusques' á 64 degrés au Sud de l'Estroit: ou ils descouvrivent un haut pays avec des montagnes pleines de neige a la facon du pays de Norvveghen: d'icy ils firent voile vers Chile en intention d'aller trouver leurs compagnons en l'ile de S. Marie: Mais ils furent portés par fortune au port de S. Iago de Valparayso; ou ils furent accablés des ennemis."

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* I quite agree with Captain James Burney ("A Chronological History," etc., Vol. I, page 13) in thinking it a "strange practice" to translate and alter proper names. The name of Magalhaens should be restored to the strait which he first sailed through.

† Herrera.

‡ Burney.

§ Herrera.

|| Herrera.

¶ De Brosses.

** Burney.

†† Page 193 (French); Fol. 80 (Latin).

Herrera's Latin version says: "Liburnica que Theodorum Gerardi vehebat, tempestatum vi versus Austrum propulsa fuit ad gradus usque 64. in qua altitudine posita ad Australem plagam solum monto sum & nivibus opertum eminus conspexit, qualis Norvvegiæ esse solet facies. Versus insulas Salomonis exporrigi videbatur. Hinc Chilam petijt & ab insula S Mariæ quo loci socios se repertutum putabat, aberrans, in portum S. Jacobi de val Parayso se recepit & cum humanitatis ac benevolentiæ officia omnia negarent indigenæ, itinere longo confectis vectoribus & commeatus indiga, in hostium manus se dedit."

De Brosses' account in 1756 is as follows: * "La même tempête qui avoit fait perdre la flotte aux deux précédents, dispersa de même les trois autres navires. Elle jetta Theodoric de Gueritk jusqu'a 64° de latitude australe. On ne nous dit pas la longitude qui serait très-nécessaire a scavoir: car peut-etre personne n'a jamais été si loin vers l'antarctique. Il y découvrit une côte d'un aspect semblable a celle de Norwege, monstueuse, couverte de neige, s'étendant, à ce qu'il paroissoit, du côté des isles Salomon. Il revint aux côtes du Chili. * * *"

Burney's account in 1806 is the following: † "The yacht commanded by Dirck Gherritz was separated from all the other ships, and was carried by tempestuous weather to the south of the *Strait*, to 64° south latitude, where they discovered a high country, with mountains, which were covered with snow like the land of Norway. Gherritz afterwards sailed to the coast of Chili, in hopes that he should there rejoin some of the fleet; but he missed the Island Santa Maria, and was taken by the Spaniards at Valparaiso.

"The lands ‡ discovered in this voyage have no place assigned them in any of the charts now extant; and as they were omitted in the charts to De Bry's collection, it is not probable that they were ever marked on any.

"The islands seen in 16° north, in the Pacific Ocean, may be conjectured to be the same which appear in the

* Page 290.

† Page 198.

‡ Page 204.

Spanish charts with the name of Gaspar Rico, but no use can be made of the description which Adams has given of them. Neither can the land seen by Captain Dirk Gherritz in 64° south be laid down from the account given; but a short notice of Gherritz land ought to be inserted on the charts, near the situation, which may be supposed to be about 5° to the west of the meridian of the western entrance of the Strait of Magalhanes, where there is room for such notice or remark, perfectly free from interference with other lands, or with any other necessary information."

Gerritz was the first navigator who positively saw land in Antarctica, and therefore he should be commemorated by having his name affixed to the place which he sighted. Two Englishmen, John Barrow, F.R.S., and Vice-President of the Royal Geographical Society in 1831,* and Dr. Webster, of the "Chanticleer,"† wrote to that effect. While we can never expect to know exactly what spot Gerritz reached, the probability is that it was some of the western Shetlands, and some of the islands west of Gerlache Strait. Under the circumstances, it seems as if the proper thing to do would be to name the archipelago west of Gerlache Strait after Gerritz, and this is perhaps most just; or else call the entire land mass south of South America, Gerritz Land, or Gerritz Archipelago, as the Germans are doing.

The discovery of Gerritz appears to have been forgotten, or rather it was not noticed at the time, and we next find Pedro Fernandez de Queros seeking for a *Tierra Austral* in 1605. His able second in command, Luis Vaez de Torres, in 1606, sighted an extended coast south of New Guinea. The same land was sighted also the same year by a Dutch vessel. In 1616, Theodoric Hertoge, in the "Eendracht," also sighted another part of this land,‡ and the voyage of Abel Tasman may be looked on as the last step in the discovery of the land, which was at first supposed to be the

* *The Journal of the Royal Geographical Society of London* for MDCCC-XXX-XXXI; London, MDCCCXXXI, page 62.

† "Narrative of a Voyage," etc., Vol. I, page 136.

‡ Burney: "A Chronological History," etc., Vol. II, pages 272, 313, 456.

one sought for, and which eventually received the name of Australia.

The belief that Tierra del Fuego extended without interruption to the regions of eternal ice was settled by the voyage round the world of the Dutchmen, Le Maire and Schouten, in 1616, when they sailed round South America and christened Cape "Hoorn."* Although not properly an antarctic voyage, yet it must be looked on as important as the first one narrowing the limits of a *Terra Australis Incognita.*

In 1643 Hendrick Brouwer's squadron sailed around Staaten Land, because the wind was unfavorable to pass Strait Le Maire.† This voyage also tended to a narrowing of the limits of a *Terra Australis Incognita.*

In 1675 Antonio de la Roché,‡ an English merchant, on a return voyage from Peru, was unable, on account of high winds and currents, to go through the Strait of "Magalhaens," or Strait Le Maire. He was driven out to sea eastward of Staaten Land, and in April, 1675, discovered a coast or one or more islands, probably those sighted by the "Leon" in 1756, and called South Georgia by Captain Cook.

Some of the Buccaneers also,§ at the end of the seventeenth and the beginning of the eighteenth centuries, reached some rather high southern latitudes. Bartholomew Sharp reached 58° 30′ south latitude, in 1681; Woode Rogers, 62° south latitude, in 1709; La Barbinais, 61° 30′ south latitude, in 1714; George Shelvocke, 61° 30′ south

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* Herrera: "Description des Indes Occidentales," etc., Amsterdam, MDCXXII, contains "Journal & Miroir de la Navigation Australe du vaillant bien renommé Seigneur Jaques Le Maire;" Chef et conducteur de deux navires Concorde et Horne; pages 105–174.

Burney: "A Chronological History," etc., Vol. II, pages 354–452.

† Burney: "A Chronological History," etc., Vol. III, pages 115, 145.

‡ Burney: "A Chronological History," etc., Vol. III, pages 395–404. Burney's is the best account in English of this voyage. He drew his materials from Francisco de Seixas y Lovera's "Descripcion Geographica de la Region Magallanica."

§ De Brosses: "Histoire des Navigations aux Terres Australes," Vol II. Burney: "A Chronological History," etc., Vol. IV.

latitude, in 1719; and Roggewin, 62° 30′ south latitude, in 1721.

In 1738–39, Lozier Bouvet, a French sea officer,* made a search for the lands discovered by the Sieur de Gonneville in 1503, which were supposed to lie south of the Cape of Good Hope.† Bouvet commanded the frigate "l'Aigle" and M. Hays the frigate "la Marie." In 49° south latitude they saw three great ice islands. On January 1, 1739, Bouvet discovered a high land covered with snow, to which he gave the name of *Cap de la Circoncision*, in memory of the day. He presented twenty *piastres* to the principal pilot of the "Aigle," who had first sighted the land. Bouvet describes it as in 54° south latitude, and 27° or 28° longitude (Paris), and as stretching from northwest to southeast, for about 8 or 10 leagues on one side and 6 on the other. The two ships beat about here for twelve days, but were never able to get close to the coast nor even to land their boats on account of the ice, the fog and the adverse winds. Then they sailed eastward in about 57° south latitude, for 425 leagues, until January 25th, always along the pack and constantly seeing whales and "sea wolves." Bouvet then went north in search of the place where Gonneville landed.

In 1756 the Spanish ship "Leon" sailed from Valparaiso for Europe, and after passing Cape Hoorn, unfavorable winds drove her eastward.‡ On June 28th, when at least 125 leagues east of the Falkland Islands, land was sighted, to the great surprise of the navigators, in 55° 10′ south latitude. The next day it was found to be a coast at least 25 leagues long, with sharp and craggy mountains. It was called the Isle de San Pedro. There is no doubt that it is the land since called South Georgia.

Captain Marion du Fresne and the Chevalier Ducles-

* De Brosses: "Histoire des Navigations aux Terres Australes," Vol. II, pages 255–259.

† It has been suggested that de Gonneville reached Madagascar, also Australia. See Burney: "A Chronological History," etc., Vol. I, pages 377–379.

‡ Burney: "A Chronological History," etc., Vol. V, pages 136–142.

meur, in the "Mascarin" and the "Marquis de Castries,"* discovered, in January, 1772, some small islands in between 46° and 47° south latitude, and about 50° 30′ to 53° east longitude. They christened them Terre d' Espérance, Ile de la Caverne, Iles Froide, and Ile Aride, but they are now known as the Crozet Islands.

Captain Yves J. de Kerguelen,† also a Frenchman, discovered, on February 12 and 13, 1772, another southern island in 49° south latitude, 69° east longitude, which has since, in memory of its discoverer, received the name of Kerguelen Island. The shores were alive with antarctic animals and birds, so that the island may perhaps be considered as an outlier of Antarctica.

Lieut. James Cook, R.N., on a voyage round the world in the ship "Endeavour," went just beyond 60° south latitude, between 74° and 75° west longitude, on January 30, 1769. When approaching New Zealand, on October 7, 1769, he wrote: "This land became the subject of much eager conversation; but the general opinion seemed to be that we had found the *Terra Australis Incognita*." ‡

Lieutenant Low states that an English geographer, Alexander Dalrymple, published a paper about 1770, asserting the existence of an antarctic continent extending north of 60° south latitude, and that Captain Cook searched for this on his second voyage round the world. Captain Cook commanded the "Resolution," and Captain Furneaux commanded the "Adventure." § At the Cape of Good Hope they found the Swedish naturalist, Dr. André Sparrman, and

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* "Nouveau Voyage à la Mer du Sud," commencé sous les ordres de M. Marion * * * et achevé * * * sous ceux de M. le Chevalier Duclesmeur * * * d'après les Plans et Journaux de M. Crozet. Paris, chez Barrois l'ainé, MDCCLXXXIII.

† Kerguelen, M. de: "Relation de deux voyages dans les mers Australes et des Indes," faits en 1771, 1772, 1773 et 1774. A Paris, chez Knapen & Fils, MDCCLXXXII; pages 21–24.

‡ Hawkesworth, John: "An Account of the Voyages Undertaken by the Order of His Present Majesty for Making Discoveries in the Southern Hemisphere." London, MDCCLXXIII.

§ Cook, James: "A Voyage Towards the South Pole and Round the World," performed in His Majesty's Ships the "Resolution" and "Adventure,"

invited him to join the expedition. From the Cape, Cook proceeded south and east, and on January 17, 1773, crossed the Antarctic Circle in 39° 35′ east longitude, and reached 67° 15′ south latitude. Here he was stopped by a pack composed of field ice, with thirty-eight ice islands in sight. He turned northward and later southward. On the 23d of February he reached 61° 52′ south latitude, 95° 2′ east longitude. Here there were so many ice islands that he gave up attempting to cross the Antarctic Circle, and continued on an easterly course until, on March 17, he reached 59° 7′ south latitude, 146° 53′ east longitude, when he bore away north.

In December, 1773, Cook again went south, and on December 22d reached 67° 31′ south latitude, 142° 54′ west longitude, where he was stopped by the pack. On January 30, 1774, he reached 71° 10′ south latitude, 106°54′ west longitude, where a great ice field, in which ninety-seven ice hills were in sight, blocked further progress. He then went in search of the *Terra Australis Incognita* that Juan Fernandez was said to have discovered.

In January, 1775, Captain Cook went south from Staaten Land, on a search for La Roché's Island. On January 14, in 53° 56′ south latitude, 39° 24′ west longitude, he sighted land, which is undoubtedly the one discovered, perhaps by Amerigo Vespucci, certainly by La Roché, and which was seen by the Spanish ship "Leon." It lies between 53° 57′ and 54° 57′ south latitude, and 38° 13′ and 35° 34′ west longitude. Cook spent several days there and renamed it the Isle of Georgia. He then stood eastward again, and on

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in the years 1772, 1773, 1774 and 1775. Second edition, London, W. Strahan & T. Cadell, MDCCLXXVII.

"Journal of the 'Resolution's' Voyage," in 1772, 1773, 1774 and 1775, on discovery of the Southern Hemisphere, by which the non-existence of an undiscovered continent, between the equator and the fiftieth degree of southern latitude, is demonstrably proved. Also a "Journal of the 'Adventure's' Voyage," in the years 1772, 1773 and 1774. Dublin, Caleb Jenkin, MDCCLXXVI.

Low, Lieut. Charles R. (H. M. Indian Navy): "Captain Cook's Three Voyages Round the World." London, George Routledge & Sons.

Sparrman, Dr. André: "Voyage au Cap de Bonne Espérance et Autour du Monde, avec le Captaine Cook." Paris, chez Buisson, MDCCLXXXVII.

January 31st sighted land in 59° south latitude, 27° west longitude, and on the same day another coast in 59° 13′ south latitude, 27° 45′ west longitude, which was named Southern Thule. On February 1st he sighted Cape Montagu, and on the 3d, in 57° 11′ south latitude, 27° 6′ west longitude, two islands, which he called the Candlemas Isles. After a vain search for Bouvet Island, he returned to the Cape.

This voyage of Cook was important, because it was the first one to circumnavigate Antarctica, and to circumscribe its limits; and also because it did away with the belief in a *Terra Australis Incognita* north of 60° south latitude.

II. VOYAGES UP TO THE DISCOVERY OF A SOUTH POLAR CONTINENT.

During the following six decades many of the discoveries in Antarctica were made by whalers or sealers, men who went out for commercial and not for scientific purposes. Some of them penetrated a good distance south, and in so doing made some important discoveries. Although their voyages added to geographical knowledge, yet about no travels is it more difficult to get information, as the discoveries in many cases seem to have been merely entered in the log books.

In 1794 the Spanish *corvette* "Atrevida" was sent to survey the Aurora Islands, which were discovered, it was said, in 1762, by the ship "Aurora."* In 1769 the ship "San Miguel" saw some islands, which it was suspected were the Auroras. In 1774 the ship "Aurora" again reported them. Three other vessels, the "Pearl" in 1779, and the "Dolores" and the "Princess" in 1790, also are said to have seen these islands. The "Atrevida" went purposely to situate them, and reported that the islands were three in number; and that the southernmost was in 53° 15′ south

* This account is compiled from Captain James Weddell's "A Voyage Towards the South Pole," pages 61-67, in which Weddell quotes the publications of the Royal Hydrographical Society of Madrid, 1809, *Memoria Segunda*, tomo 1°, pages 51, 52, and appendix to same, Vol. I, page 213, No. IV.

latitude, 47° 57′ west longitude; the second in 53° 2′ south latitude, 47° 55′ west longitude; and the third in 52° 37′ south latitude, 47° 43′ west longitude. The Spanish officers, however, said that none of the circumstances connected with the islands which they saw agreed with those reported of the Auroras.*

The earliest discovery by an American sealer appears to be the following: † "Swain's Island, latitude 59° 30′ south, longitude 100° west by calculation, discovered by Captain Swain, of Nantucket, in 1800. Resorted to by many seals."

In 1808 Bouvet Island was seen by two English whaling vessels,‡ the "Snow Swan," Mr. James Lindsay, master, and the "Otter," Mr. James Hopper, master. The "Swan" sighted Bouvet Island on October 6, 1808, and the "Otter" on October 10, 1808. They recognized the *Cap de la Circoncision*, but could not land, on account of fogs and ice. The island was determined to be in 54° 15′ south latitude, 4° 15′ east longitude.

In the spring of the year 1812, Mr. Edmund Fanning § was appointed commander of an American discovery expedition, to consist of the ships "Volunteer" and "Hope," intended for the exploration of the Southern Hemisphere and a voyage round the world. The expedition was on the point of sailing when, owing to the breaking out of war, it was given up. About this time, however, it is barely possible that Gerritz Land was rediscovered. Dr. Fricker || says: "At all events, probability points that way, and it is certain that the English hydrographer, James Horsburgh, told the German geographer, Heinrich Berghaus, that the

* See *post.*

† Fanning, Edmund: "Voyages Round the World; with Selected Sketches of Voyages to the South Seas, North and South Pacific Oceans, China," etc., between the years 1792 and 1832. New York, Collins & Hannay, MDCCC-XXXIII, page 447.

‡ Burney: "A Chronological History," etc., Vol. V, pages 35-37.

§ "Voyages," etc., pages 492-494.

"Executive Documents," 26th Congress, 1st Session, 1839-40, Vol. II, Doc. No. 57: "Memorial of Edmund Fanning."

|| Fricker, Dr. Karl: "The Antarctic Regions," London and New York, 1900, page 47. A translation of "Antarktis, Bibliothek der Länderkunde," Berlin, Schall & Grund, 1898.

island group had been a station for American seal hunters since 1812. The motive for keeping its existence secret was the desire to retain the sole use of the station for their own profit." It would seem probable that Mr. Horsburgh's information was incorrect, since Fanning says nothing of the matter. Still, further evidence may yet be found.

Mr. William Smith,* master of the brig "Williams," of Blythe, took an unusually southerly course round Cape Hoorn in February, 1819. Apparently by accident, on February 19th, he sighted some islands in 62° 17′ south latitude, 60° 12′ west longitude. On October 15th following he sighted the same islands, and this time examined them more carefully, christening several of them and calling the whole group New South Shetland. He thought he could distinguish through the telescope trees similar to the Norway pine. Mr. Smith appears to have gathered the impression that the Shetlands were a more or less connected mass of land, and in fact he speaks of some of them as the mainland, which appears to be the first hint, since the time of Captain Cook, that there was anything more than small islands in the Antarctic. His chart, however, shows that he was always north of the Shetlands.

Captain James P. Sheffield † and Supercargo William A. Fanning sailed in the brig "Hersilia," of Stonington, in July, 1819, on an exploring and sealing voyage, due to the initiative of Mr. Edmund Fanning, who had read the account of Gerritz's discovery of land at the south of Cape Hoorn, and had also been at South Georgia at the breaking up of the winter ice and noticed that ice islands came floating there after gales from the W. S. W.; he believed, therefore, that there was land in that quarter, and this was the inducement for the search. On the return of the "Hersilia," Sheffield and Fanning reported that they had seen

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*The *Edinburgh Philosophical Journal*, Vol. III, Edinburgh, 1820, pages 367–380, Art. XXI: "Account of the Discovery of New South Shetland, with Observations on its Importance from a Geographical, Commercial and Political Point of View, with Two Plates;" by Mr. J. Miers. Communicated by Mr. Hodgskin.

† Fanning, Edmund: "Voyages Round the World," etc., pages 428–434.

the Aurora Islands, and then proceeded south, and that in about 63° south latitude, in February, 1820, they had found several islands. One they called Mount Pisgah Island, others Fanning's Islands, and another Ragged Island, on which they effected a landing at Hersilia Cove, the second recorded landing in Antarctica. They did not rename the group, believing it was Gerritz Land. They captured many seals, and this voyage was the forerunner of those which resulted in the extermination of the Antarctic fur seal.

Mr. Edward Bransfield, R.N.,* sailed from Valparaiso on December 20, 1819, in the brig "Williams," to examine Mr. Smith's newly found islands. He reached the Shetlands on January 16, 1820, in 62° 26′ south latitude, 60° 54′ west longitude. Three days afterwards, about 2° more to the eastward, he anchored in an extensive bay and was able to land, apparently the first time any one did so in Antarctica. He found also some stunted grass, and this seems to be the first time vegetation was noticed in Antarctica. Like Mr. Smith, Bransfield appears to have considered the Shetlands as a more or less connected mass of land, for Dr. Slaney's involved account speaks of them as a line of coast which "appeared high, bold and rugged." He says further that the land was traced 9° or 10° east and about 3° north and south, and that they could not ascertain whether it was part of a continent or only a group of islands. "If it is insular, there must be *some* of an immense extent, as we found a gulf nearly 150 miles in depth, out of which we had some difficulty in finding our way back again." According to the English Admiralty charts, Bransfield's course must have been north of the Shetlands, then eastward, then southward, along about the meridian of 52° 30′ west longitude, to about 64° 30′ south latitude, and this cruise is probably what Dr. Slaney refers to as a "gulf." Bransfield may have sighted Joinville Island.

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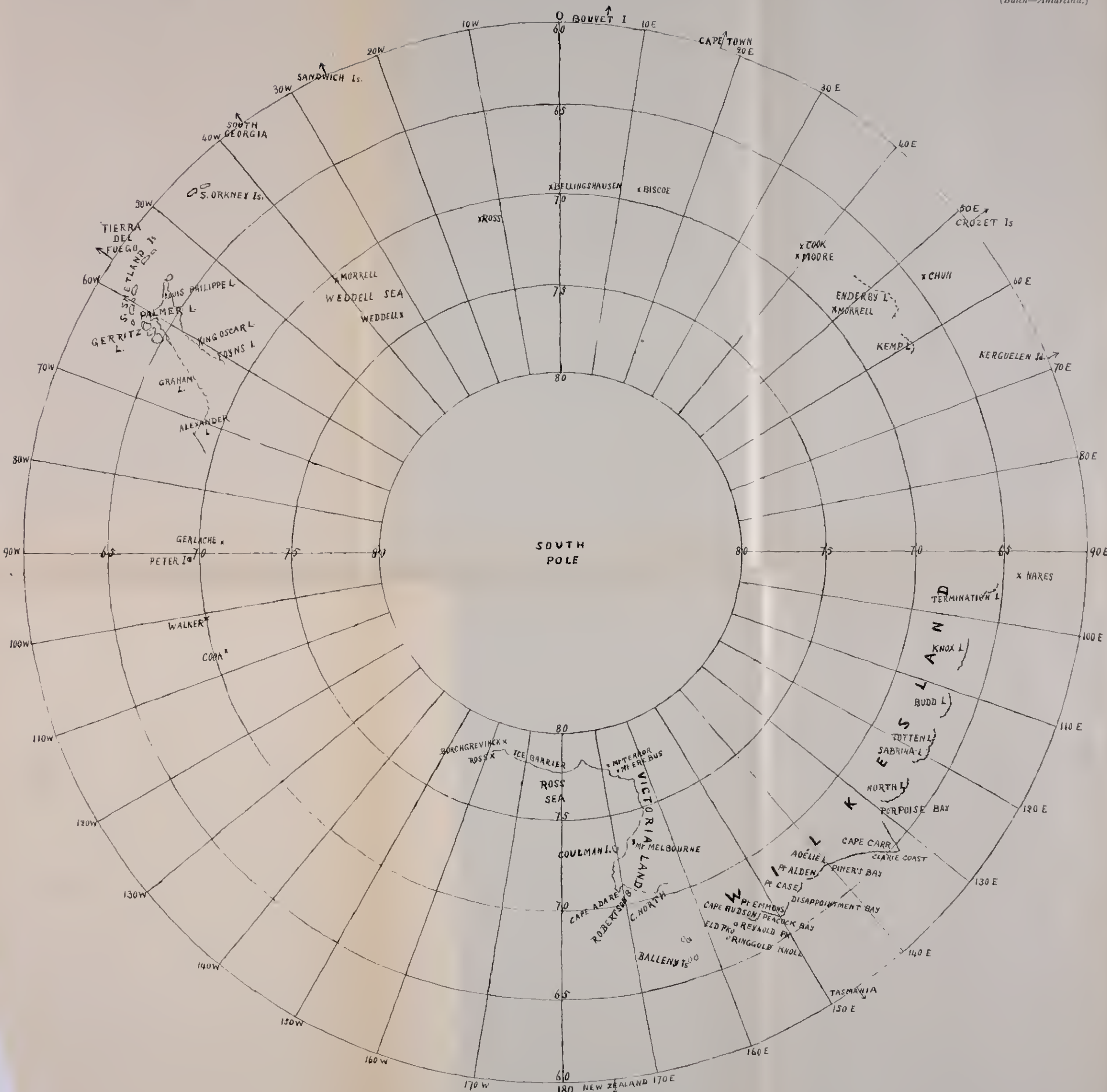
* The *Edinburgh Philosophical Journal*, Vol. IV, Edinburgh, 1821, pages 345–348, Art. XVII: "Notice of the Voyage of Edward Bransfield, Master of His Majesty's Ship 'Andromache,' to New South Shetland." [By Dr. H. M. S. Slaney.]

Captain Nathaniel B. Palmer, an American sealing captain, comes next in chronological order; and I quote his first two voyages in full, because of their importance in the history of Antarctic discovery.*

"The next season after the 'Hersilia's' return from the South Shetlands, a fleet of vessels, consisting of the brig 'Frederick,' Captain Benjamin Pendleton the senior commander, the brig 'Hersilia,' Captain James P. Sheffield; schooners 'Express,' Captain E. Williams, 'Free Gift,' Captain F. Dunbar, and sloop 'Hero,' Captain N. B. Palmer, was fitted out at Stonington, Connecticut, on a voyage to the South Shetlands. From Captain Pendleton's report, as rendered on their return, it appeared that while the fleet lay at anchor in Yankee Harbor, Deception Island, during the season of 1820 and 21, being on the lookout from an elevated station on the mountain of the island during a very clear day, he had discovered mountains (one a volcano in operation) in the south; this was what is now known by the name of Palmer's Land; from the statement it will be perceived how this name came deservedly to be given to it, and by which it is now current in the modern charts. To examine this newly discovered land, Captain N. B. Palmer, in the sloop 'Hero,' a vessel but little rising 40 tons, was despatched; he found it to be an extensive mountainous country, more sterile and dismal, if possible, and more heavily loaded with ice and snow, than the South Shetlands; there were sea leopards on its shore, but no fur seals; the main part of its coast was ice bound, although it was in the midsummer of this hemisphere, and a landing consequently difficult.

"On the 'Hero's' return passage to Yankee Harbor she got becalmed in a thick fog between the South Shetlands and the newly discovered continent, but nearest the former. When this began to clear away, Captain Palmer was surprised to find his little barque between a frigate and sloop of war, and instantly run up the United States flag; the frigate and sloop of war then set the Russian colors. Soon

* Fanning, Edmund: "Voyages Round the World," etc., pages 434–440.



Sketch chart of Antarctica,
Drawn by Edwin Swift Balch, March, 1901.

after this a boat was seen pulling from the commodore's ship for the 'Hero,' and when alongside, the lieutenant presented an invitation from his commodore for Captain P. to go on board: this of course was accepted. These ships he then found were the two discovery ships sent out by the Emperor Alexander of Russia, on a voyage round the world. To the commodore's interrogation if he had any knowledge of those islands then in sight, and what they were, Captain P. replied, he was well acquainted with them, and that they were the South Shetlands, at the same time making a tender of his services to pilot the ships into a good harbor at Deception Island, the nearest by, where water and refreshment such as the islands afforded could be obtained; he also informed the Russian officer that his vessel belonged to a fleet of five sail, out of Stonington, under command of Captain B. Pendleton, and then at anchor in Yankee Harbor, who would most cheerfully render any assistance in his power. The commodore thanked him kindly; 'but previous to our being enveloped in the fog,' said he, 'we had sight of those islands, and concluded we had made a discovery; but behold! when the fog lifts, to my great surprise, here is an American vessel apparently in as fine order as if it were but yesterday she had left the United States; not only this, but her master is ready to pilot my vessels into port; we must surrender the palm to you Americans,' continued he, very flatteringly. His astonishment was yet more increased when Captain Palmer informed him of the existence of an immense extent of land to the south, whose mountains might be seen from the masthead when the fog should clear away entirely. Captain Palmer, while on board the frigate, was entertained in the most friendly manner, and the commodore was so forcibly struck with the circumstances of the case, that he named the coast then to the south Palmer's Land; by this name it is recorded on the recent Russian and English charts and maps which have been published since the return of these ships. The situation of the different vessels may be seen by the plate: they were, at the time of the lifting of the fog and its going off to the eastward, to the south, and in sight

of the Shetland Islands, but nearest to Deception Island. In their immediate neighborhood were many ice islands, some of greater and some of less dimensions, while far off to the south the icy tops of some two or three of the mountains on Palmer's Land could be faintly seen; the wind at the time was moderate, and both the ships and the little sloop were moving along under full sail.

"The following season, in 1821–22, Captain Pendleton was again at Yankee Harbor with the Stonington fleet: he then once more despatched Captain Palmer in the sloop 'James Monroe,' an excellent vessel of upwards of 80 tons, well calculated for such duties, and by her great strength well able to venture in the midst of and wrestle with the ice. Captain Palmer reported on his return that, after proceeding to the southward, he met ice fast and firmly attached to the shore of Palmer's Land; he then traced the coast to the eastward, keeping as near the shore as the ice would suffer; at times he was able to come along shore, at other points he could not approach within from one to several miles, owing to the firm ices, although it was in December and January, the middle summer months in this hemisphere. In this way he coasted along this continent upwards of fifteen degrees, viz., from 64 and odd, down below the 49th of west longitude. The coast, as he proceeded to the eastward, became more clear of ice, so that he was able to trace the shore better; in 61° 41′ south latitude, a strait was discovered, which he named Washington Strait; this he entered, and about a league within came to a fine bay, which he named Monroe Bay; at the head of this was a good harbor; here they anchored, calling it Palmer's Harbor. The captain landed on the beach among a number of those beautiful amphibious animals, the spotted glossy-looking sea leopard, and that rich golden-colored noble bird, the king penguin; making their way through these, the captain and party traversed the coast and country for some distance around, without discovering the least appearance of vegetation excepting the winter moss. The sea leopards were the only animals found; there were, however, vast numbers of birds, several different species of the pen-

guin, Port Egmont hens, white pigeons, a variety of gulls, and many kinds of oceanic birds; the valleys and gulleys were mainly filled with those never dissolved icebergs, their square and perpendicular fronts several hundred feet in height, glistening most splendidly in a variety of colors as the sun shone upon them. The mountains on the coast, as well as those to all appearance in the interior, were generally covered with snow, except when their black peaks were seen here and there peeping out."

Captain Palmer made numerous other voyages, some of which appear to be unrecorded. He certainly made one in 1828–29, for he is mentioned by Dr. Webster, of the "Chanticleer." In 1829–30, Captain B. Pendleton and Captain Palmer,* in the brigs "Seraph" and "Annawan," made a cruise north and west of Palmer Land. Some scientists went on this expedition, among whom were Messrs. J. N. Reynolds and Watson. Mr. Reynolds † afterwards took a leading part in the formation and start of the United States Exploring Expedition, and in urging Congress in 1836 to send the latter, he said, among other things: ‡ "It was in company with this same Captain Palmer, during my late voyage to the South Seas, that I visited the whole of this extensive group of islands lying north of the coast of

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* Fanning, Edmund: "Voyages Round the World," etc., pages 478–491. Fanning may have had more knowledge than is apparent from his book of the extent of the western mainland, for on page 476 he says: "but from the information the author has in his possession, it is presumed that the continent of Palmer's Land does not extend further west than to the one hundredth degree of west longitude." This is, probably, the only authoritative hint of the existence of the South Polar Continent before the discovery by Wilkes. Fanning wished to have the Antarctic explored scientifically, and urged the matter in a paper: "Memorial of Edmund Fanning; To illustrate the views in a petition presented to Congress, praying that a national discovery and exploring expedition be sent to the South Seas," etc., December 18, 1833; 23d Congress, 1st Session. Referred to the Committee on Naval Affairs and ordered to be printed.

† "Address on the Subject of a Surveying and Exploring Expedition to the Pacific Ocean and South Seas." Delivered in the Hall of Representatives on the evening of April 3, 1836, by J. N. Reynolds. New York, Harper & Brothers, 1836.

‡ Address, etc., page 34.

Palmer's Land, the extent of which neither we nor any subsequent navigators have as yet ascertained; though a British vessel touched at a single spot in 1831, taking from it the American and giving it an English name." Mr. Reynolds also gave an almost identical account as that of Fanning of the meeting of the Russian commander and the American sealing captain, and of the naming of Palmer Land.

Dr. W. H. R. Webster,* of the "Chanticleer," has fortunately recorded his impressions of Palmer, for, thanks to him, we get a glimpse of the personality of the discoverer of Palmer Land. "Early on the following morning, Sunday, 25th October, Captain Foster left us, in quest of a harbour for the reception of the "Chanticleer," while the pendulum experiments were going forward. After examining New Year's Harbour, which he did not approve of, in his way along the coast he discovered an American schooner at anchor in one of the creeks: the name of the schooner was the "Penguin" of Stornington [*sic*]: and the reception he met with from Captain Palmer, who commanded her, was most kind. Captain Palmer immediately offered to conduct the "Chanticleer" into the creek, which he had named North Port Hatchett. When he made his appearance on board the brig with Captain Foster, we took him for another Robinson Crusoe in the shape of some shipwrecked mariner. He was a kind and good-hearted man; and thinking that they would be a treat to us, had brought with him a basket of albatross's eggs, which were to us a most acceptable present. How completely does this little incident, trifling as it may appear, prove the justness of Captain Hall's observations in his useful little work entitled 'Fragments of Voyages,' that it is the time and manner of making a present that gives it all its value. * * * On the following day, under the care of Captain Palmer, the "Chanticleer" was safely anchored in the beautiful little harbor of North Port Hatchett."

The account by Fanning of Palmer's first two voyages

* "Narrative of a Voyage," etc., Vol. I, pages 98–99.

proves several facts: (1) That the land discovered, visited and perhaps even landed on by Palmer is the western mainland of Antarctica; (2) that Palmer, therefore, possibly was the first to sight the mainland of Antarctica; (3) that as Palmer on his journey along the coast went eastward, he is, therefore, the first who coasted along the northern shore of the western mainland, possibly for its entire length; (4) that it is this northern coast which was called Palmer Land by the American sealers. It is the coast extending from Gerlache Strait on the west, to at least the point indicated in the statement of Admiral Wilkes:* "I place the eastern extremity of Palmer's Land, or Mount Hope, in longitude 57° 55′, W., latitude 63° 25′ S." This is Palmer Land, and the name ought to be restored to it.†

In 1819–21 a Russian expedition, under Captain F. G. Bellingshausen, in the "Vostok," and Captain Lazarew, in the "Mirny," circumnavigated Antarctica.‡ They left Kronstadt in 1819, and in December sailed along the south coast of South Georgia. On January 3 and 4, 1820, they discovered the Traversey Islands, in 56° 41′ south latitude, 28° 9′ west longitude. On the 8th they determined that the Candlemas Isles were small islands and not a coast. They then sailed south and east. On January 28th, Bellings-

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* "Narrative U. S. E. E.," Vol. I, page 136.

† Lieutenant de Gerlache, in his recent paper "Notes sur les Expéditions," etc., *Société Royale Belge de Géographie, Bulletin*, vingt quatrième Année, 1900, page 391, appears to hold this opinion. In the same article, at page 393, M. de Gerlache says: "During the years 1820, 1821 and 1822, seven ships were lost at the Shetlands, almost all during easterly storms. The men of one of these ships were obliged to winter on the coast; during many months they endured the greatest privations." This appears to be the first time any one wintered in Antarctica.

‡ Good short accounts of Bellingshausen's voyage are:

Bellingshausen: "Bibliothèque Universelle des Voyages," par M. Albert Montémont, Paris, MDCCCXXXIV, Tome XXI, pages 431–448.

Lowe, F.: "Bellingshausens Reise nach der Südsee und Entdeckungen im Südlichen Eismeer;" *Archiv für wissenschaflliche Kunde von Russland*, A. Erman, Berlin, 1842, Vol. II, pages 125–175. The narrative of Bellingshausen's voyage has been published in full only in Russian. Herr Lowe gives the title: "Dwukratnya isiskania w' Jujnom Ledowitom Okeanje i plawanie wokrug swjeta," etc., St. Petersburg, 1831. I have not seen this book.

hausen reached 69° 21′ south latitude, 2° 15′ west longitude, and on February 2d, 66° 25′ south latitude, 1° 11′ west longitude, at both of which positions he was stopped by the pack. He then steered eastward, and on February 17th reached 69° 6′ south latitude, and on the 19th, 68° 5′ south latitude, 16° 37′ east longitude. Later he reached 66° 53′ south latitude, 40° 56′ east longitude, where he thought land must be near, on account of the numbers of birds.

The following southern summer, Bellingshausen started from Sydney and sailed south and east. M. Montémont says: "On the 11th of January, 1821, we discovered, in 69° 30′ south latitude, an island, which we named in honor of the founder of our navy, Peter I Island. The 17th of the same month we discovered a coast in the same latitude, to which, in honor of the sponsor of our journey, we gave the name of Alexander I. The lands are surrounded with ice, which prevented us from approaching them and examining them near by. The discovery of these two islands is moreover remarkable in that of all these lands they are the most southerly which have yet been discovered in this hemisphere." Herr Lowe says: "The sudden change in the color of the water led Captain Bellingshausen to believe that this [Alexander] land must be of considerable size." From here Bellingshausen sailed to the Shetlands, to which he gave Russian or Napoleonic names: Borodino, Smolensk, Leipzig, Waterloo (James Island), Mordwinow (Elephant Island), etc. He then returned home via the Orkneys and South Georgia.

Bellingshausen's voyage is important, for he narrowed considerably the unexplored regions of the South Pole, and crossed six times the Antarctic Circle, within which he sailed long distances. He may have been the first to sight the mainland of Antarctica by his discovery of Alexander Land.

[*To be continued.*]

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.*

By George W. Colles, A.B., M.E.

(*Continued from p. 235.*)

MACHINES FOR ALTERNATING AND POLYPHASE CURRENTS.

What gave the great impulse to the further development and perfection of rotary current-transforming devices was, needless to say, the discovery of the properties of polyphase currents by Tesla and Ferraris and their publication in 1888. Without this discovery, electrical engineering progress would probably have been directed into continuous rather than alternating-current channels, as the simple alternating current is, in general, unsatisfactory for any purpose except lighting.

But the polyphase currents themselves were known for many years before that discovery; in fact, an old machine of Gramme is shown by Thompson,[28] which is adapted to produce simultaneously currents of four phases, in octature, operating in as many different circuits.

It is not surprising, therefore, that the first continuous-alternating current transformer which we shall have occasion to mention is in reality a four-phase machine, though not recognized by its author as such; nor that the first transformer for polyphase currents is the invention of Tesla.

Before proceeding to the consideration of machines with rotating parts, it will be well to consider what transformations can be made by stationary apparatus (already referred to on page 210),† and the nature of the apparatus.

The peculiar property of polyphase currents is their ability to produce a rotating constant magnetic field without any corresponding mechanical rotation of the parts of the machine. Hence, wherever in apparatus of this description a continuous is replaced by a polyphase current, we

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* A thesis presented in candidature for the degree of Master of Science, in the Columbian University, May, 1900.

[28] "Dynamo Electric Machinery," 4th ed., p. 641.

† See March number of this *Journal*.

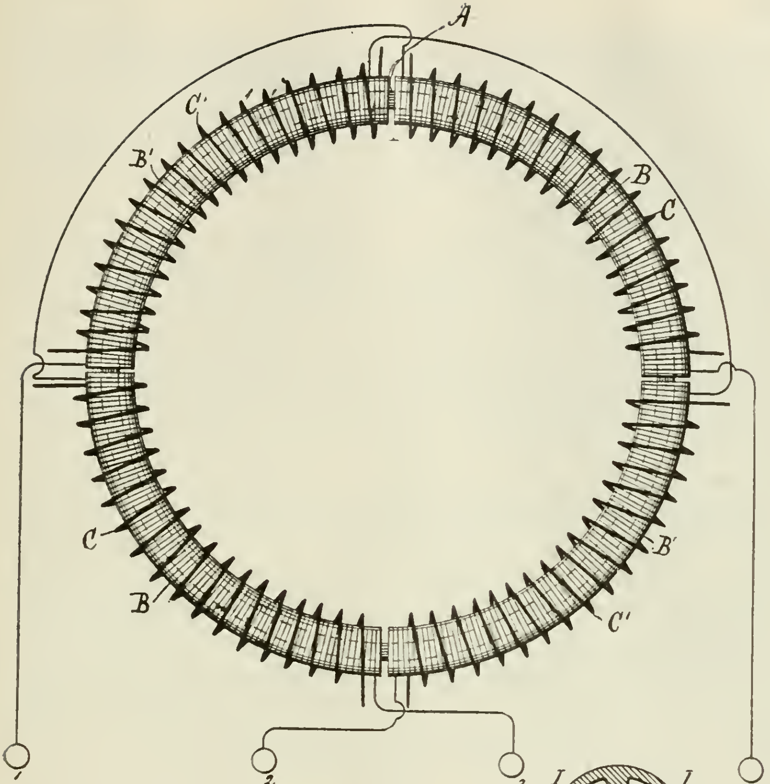
may dispense with the rotating parts, sliding connections, commutators, etc., which are necessary to the former. Herein lies their great advantage.

Hence, if we desire to transform one polyphase current into another, we may simply take our induction ring (or dynamotor armature), wind both sides appropriately for the respective polyphase circuits, connecting them directly thereto, and our apparatus is complete without any rotating parts or exciting magnetic fields. A machine of this sort is seen in *Fig. 1* of Plate XIV.[29] Here the primary coils $B\ B'$ produce a rotating field in the core with free poles at opposite ends of a diameter, precisely the same as in the ring type of inductorium; and this in like manner induces similar polyphase currents in the secondary coils $C\ C'$. As the primary and secondary coils are independent, we may have any pressure ratio between them. Moreover, although in the machine shown both circuits are of the two-phase species, this is not necessary; it is only necessary that a rotating field of constant strength be induced in the core by the action of the primary circuit, which, as is well known, can be equally well produced by any number of phases; conversely, this rotating field may be made to induce a current of any *other* desired number of phases in the secondary winding by simply winding the latter in the appropriate manner. This gives us a *phase* transformation. We cannot, however, accomplish a frequency transformation by this method; for the frequency in both coils will be equal to the frequency of rotation of the magnetic field, multiplied by the number of free poles formed therein; and this is necessarily the same for both.

This simplest form of polyphase transformer has, therefore, this advantage not possessed by some more complex forms, that we can accomplish a phase transformation with perfect ease along with our pressure transformation; but it has the very considerable disadvantage of a so-called "open magnetic circuit," to wit, free poles at different points of the ring. We can partially overcome this defect

[29] From Tesla's patent, No. 381,970, of May 1, 1888.

Fig. 1.



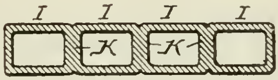


Fig. 2.

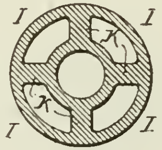


Fig. 3.

Fig. 4.

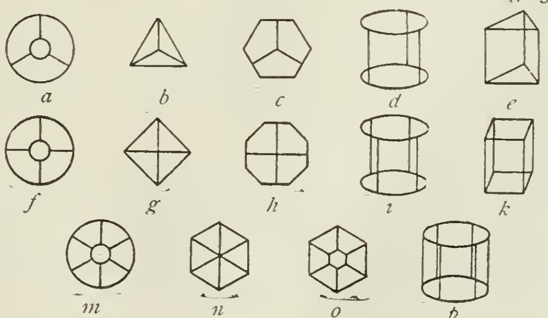


PLATE XIV.—Polyphase transformation. *Fig. 1*, Tesla's ring transformer. 1888. *Figs. 2–4*, core-shapes for polyphase transformers.

by surrounding the coils with a hollow torus of iron, or by an external ring, or by placing within the ring an iron center; and a recently invented form (Plate XXII) which practically overcomes it altogether will be referred to hereafter; but in general, where no phase transformation is desired, other forms are preferable.

We may, again, look at the transformation of polyphase currents from another standpoint, which has reference to their alternating rather than to their direct current analogies; that is to say, we may separate them into their constituent phases and transform each phase separately by an ordinary *A C* transformer. Proceeding a step further, it is seen that we may save both metal and hysteresis losses by linking our several cores together, as in *Fig. 2* of Plate XIV; another step, and they are wholly consolidated, as shown in *Fig. 3*. This form, as is easily seen, is the equivalent of bending the core of *Fig. 2* into a ring and connecting the two ends. The coils are wound upon the radial portions *K*, *K*; and by arranging them in proper sequence of phase, the currents in the successive coils are made to rise and fall in order of rotation. The magnetic flux induced in the several legs of the core rises and falls in synchronism with the current; it is not, however, a rotating flux, properly speaking, as in the ring transformer, but a polyphase—in this case a four-phase (or two-phase) flux; for no free poles exist at any time around the ring, and the flux merely shifts from one leg of the core to the next in order. We may, moreover, if desired, wind the coils upon the circular instead of the radial parts of the core, or upon both; as for instance, by placing the primary coils upon the legs, the secondary upon the rim, we should obtain a secondary circuit whose phases are in octature with the primary.

An evident equivalent to the spoked-wheel form of transformer is that shown in outline in *Fig. 4 i*, wherein the spokes are replaced by parallel columns joined at their ends by two equal rings or solid heads; for a three-phase current we might use a core having six legs joined up like a tetrahedron (*Fig. 4 b*); and many other forms readily suggest themselves, a variety of which are exemplified in *Fig. 4*.

These forms are intended to be used where only a pressure transformation is desired; a phase transformation may also be accomplished, as, for instance, from two-phase to three-phase current, by adding to the four legs of *Fig. 3* three other legs equally spaced about the center and carrying the secondary coils. A defect of this arrangement, however, is too large magnetic leakage. Even from the core of *Fig. 3* as it stands we may obtain a three-phase current by appropriately distributing the three secondary-circuit cells equably about the four sections of the ring of the core. Such an arrangement resembles in theory the arrangement for phase-transformation shown in some recent patents, which will be referred to later on.

A special case, however, of these methods just referred to, is the invention of Scott[30] (see Plate XV) for transforming two-phase into three-phase currents, and may be here noticed. This method has the great merits of perfect simplicity and high efficiency. Two ordinary *A C* transformers are used, whose primaries may have an equal number of turns, but the secondary coil of one transformer has a less number of turns than the other in the ratio of

$$\frac{\sqrt{3}}{2},$$

while the second has a lead attached to the center of its secondary which is connected, as shown, to one end of the secondary of the first-named coil. The primaries are placed across the respective mains of the two-phase circuit. The arrangement of the secondaries gives a branched or Y-shaped circuit, and the effect of the bisected secondary of the second transformer is to advance the phase of the current in one branch by 30°, and to retard the phase of that in the other branch by the same amount, thus producing the required phase difference for a three-phase circuit.

Passing now to the consideration of species transformation, we will first speak briefly of the alternate-polyphase transformation—No. (4) on page 209*—as the only one which

[30] Patent No. 521,051, of June 5, 1894.

* March number of this *Journal.*

can be accomplished by stationary means, and for this very reason one of the most important. The transformation from polyphase to alternating currents presents, of course, no difficulty. It is when we attempt to reverse the opera-

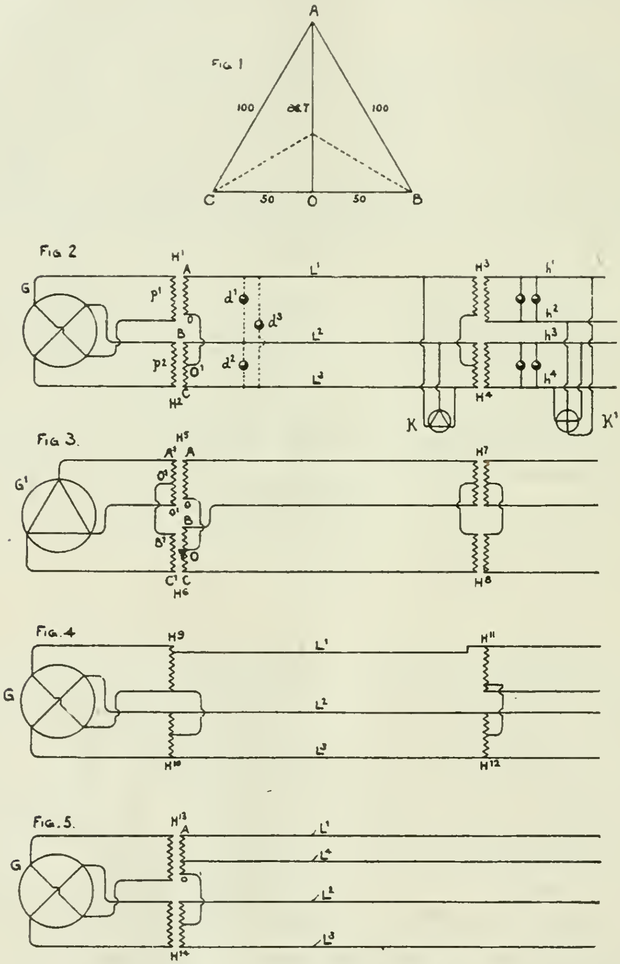


PLATE XV.—Scott's method of phase transformation. 1894.

tion, and produce a polyphase from an alternating current, that we are confronted with a serious practical problem. The case is precisely analogous to the mechanical one of converting rotary into reciprocating, and reciprocating into

rotary motion. For the first, a crank-and-pitman connection is all that is necessary. For the second, we need in addition a *fly-wheel* to store up energy at certain parts of the revolution, and give it up again at the dead points, during which no energy is imparted to the rotating shaft. Just so it is in the parallel electrical case; for, since the energy imparted by the alternating current is periodically at zero, while the polyphase energy flow is constant, some energy must be stored up in the transforming apparatus during the maxima, to be given out at the zero points.

This energy may be stored either electrically or mechanically. Not that these two include all the possibilities, but these are means ready to hand, and the only ones which have so far been employed. As mechanical means we have, of course, the fly-wheel or momentum of moving parts—which implies, of course, a machine with moving parts. As electrical means we have two: the induction coil and the condenser; the first of which stores the energy electromagnetically, in an electromagnetic field of force, the second electrostatically, in an electrostatic field of force; the first in producing a lagging, the second a leading current. We may therefore, it is clear, by dividing a monophase circuit into two branches, and introducing inductance into one, and capacity into the other, produce in the two branches the phase-difference appropriate to a two-phase, three-phase, or in general, any desired polyphase circuit. This, then, sums up the means so far known to us for transforming alternating into polyphase currents without the use of a transformer; and all such transformers hitherto made are based on these means.

The disadvantages of such a mode of transformation are considerable. In the first place the efficiency of the transformation is low, due principally to the absorption of energy by hysteresis in the reactance coil, which, as calculated by Professor Fessenden,[31] has an efficiency as an accumulator of energy not greater than 75 per cent.; whereas that of a fly-wheel is practically 100 per cent.; so that, all

[31] Fessenden, in *Elec. World*, V. 26, p. 618.

things considered, the highest theoretical efficiency of conversion of such an apparatus is about 91⅓ per cent.; which, as he justly remarks, is not satisfactory. In the second place, condensers of sufficient capacity for this work, in which the frequency is generally low, are expensive, and not always reliable. Thirdly, the regulation is bad, due to the interdependence of the two circuits. These several defects combine to render the use of a rotary transformer preferable in many or most cases, where such transformation is necessary, particularly on a large scale; on the other hand, for small isolated motors, and particularly for starting motors of the synchronous alternating type, such means are very useful.

Bradley[32] has devised a transformer, described by him before the American Institute of Electrical Engineers, in which he uses a condenser to produce a leading branch-current in the high-voltage primary, and winds this and the original current on transforming coils so as to produce in low-voltage secondary wires a three-phase current, in the same manner as the Scott *2 P C–3 P C* transformer described above (page 267). The three-phase secondary current, however, is properly adjusted as to its phase-differences only at full load; at light loads it approaches to a single-phase current.

The problem of producing a satisfactory polyphase from an alternating current has a special bearing upon the railway power question; for here we are practically limited to the alternate current for long-distance work, and we are also practically limited to a single wire or conductor for conveying the energy from the line to the track. The satisfactory solution of the problem therefore turns on the production of a satisfactory motor or means for operating the motor from a monophase circuit, such that the motor shall start easily under full load; and that solution has not yet, apparently, been forthcoming.

Having now considered the principal stationary apparatus which have been devised for effecting different forms of

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[32] *Trans. A. I. E. E.*, V. 12, p. 505, September 25, 1895.

current transformation, we are prepared to return to machines having moving parts, of which the most important is

THE ROTARY TRANSFORMER.

The Two-Coil Transformer.—Under this head we include all those machines which resemble the dynamotor in having a single field and a two-coil armature, but which are intended to be used with an alternating current in one or both coils. The distinction, as we shall see, is an essential one. In fact, these machines belong more properly to the rotary-transformer class than to the dynamotor class, as the armature reactions and much of the mathematical theory are common to both.

The machine shown in Plate XVI, which is the same as that heretofore referred to (see pages 226* and 263), is from a patent issued to Van Depoele[33] in 1882, and is apparently the first of either the dynamotor or rotary transformer type. It is interesting as an apparent near approach to the polyphase machine, although in fact it is more properly considered, so far as its secondary circuit is concerned, only an adaptation of the Gramme polyphase winding mentioned on page 263 above. The primary is of the ordinary closed-coil Gramme pattern, but the secondary is divided into four independent quadrants, one end of each being grounded on the frame, while the other is connected to a single slip-ring. The effect is to produce four independent line circuits, but with a common return (see diagram, lower figure). The patentee, however, did not observe the nature of the four-phase circuit thus produced, nor that the return wire was not necessary except as a regulator, as no current will flow through it when the load on each pair of opposite line-wires is equal.

The two-coil rotary transformer has at least three considerable advantages over the single-coil machine, to wit, that a pressure transformation may be made along with the species transformation; that the two circuits are entirely

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* March number of this *Journal*.

[33] No. 257,990, of May 16, 1882.

independent; and that the two windings may be made on different plans according to the form most suited to the kind of current used in the respective circuits, as is done in the Van Depoele machine just explained. It has not, however, come into extended use, probably owing to the

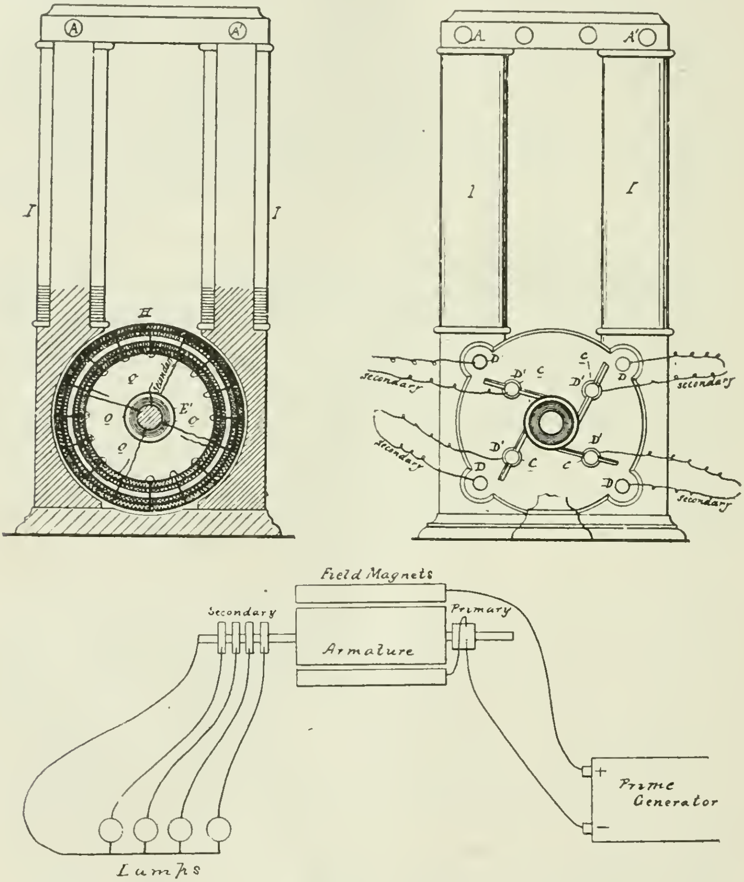

PLATE XVI.—Van Depoele's two-coil *D C* polyphase transformer. 1882.

fact that where a pressure transformation and species transformation are found desirable in one machine, the inductorium or stationary form with rotating commutator is deemed preferable.

We need not therefore delay longer upon this type,

especially as no very important improvements or varieties are set before us; we make, however, one exception, in the extremely interesting, ingenious and versatile machine invented by Lieut. F. J. Patten.[34] As this, however, is really only a variety or modification of his one-coil machine, it will be convenient to defer further explanation of it until after considering the properties of the one-coil transformer.

Where it is desired to run a pair of transformers to operate a three-wire continuous current circuit from a primary alternating or polyphase circuit, the two machines being connected up in parallel to the primary circuit, single-coil transformers are an impossibility, because, as pointed out by Field,[35] such connection, owing to the positive secondary terminal of one machine being joined to the negative secondary terminal of the other, would result in a periodic short-circuiting of the primary circuit. Hence in this case a two-coil machine must be used. Such a machine has been patented to Rice.[36]

A mode in which a single one-coil transformer may be connected to a three-wire system will be hereafter described (page 279).

The Single-Coil Rotary Transformer.—The single-coil rotary transformer may be defined as a two-coil transformer whose two coils have been made equal to each other and then merged into one. This is the standpoint from which we have approached it; but it is in no wise indicative of its origin. Indeed, so far from the two-coil having given rise to the one-coil transformer, quite the contrary is the fact; for, setting aside a few isolated machines—principally of the dynamotor order and intended, in general, only incidentally for dealing with alternating currents—which are disclosed by the patent records, the two-coil machine has only come into practical use long after the one-coil, and then only as an improvement over the latter for certain uses, as explained on the preceding page.

[34] *Elec. World*, V. 26, p. 669, Dec. 21, 1895.
[35] *Proc. I. E. E.*, V. 27, p. 697, Nov. 24, 1898.
[36] No. 516,836, of Mar. 20, 1894.

As a matter of fact, the origin of the rotary transformer is quite different from and independent of that of the dynamotor. Its first appearance is not as a transformer at all, but as a dynamo adapted to produce both direct and alternating current according to the needs of its owner. Such a machine, according to Professor S. P. Thompson,[37] has been in the Finsbury Technical College since 1885. This machine consisted of a bipolar Gramme armature with ordinary commutator, with the addition of two insulated slip-rings at the other end of the armature, these rings being connected to two points on the winding at opposite ends of a diameter. Of its origin we are not informed; nor can we certainly say that the device had not been independently and contemporaneously employed by others. It was not, however, patented in this country until 1888, when a patent was issued to Bradley.[38] This machine is illustrated in Plate XVII. Here also it appears that the main object of the inventor was to increase the capacity of a Gramme-wound alternate-current dynamo, by utilizing the "waste space" on the armature, which occupies about one-half of its periphery. To this end he connects four slip-rings to symmetrical points on the armature, thus doubling its capacity (see *infra*, under "Output"), as he claims, each pair of opposite quadrants being alternately idle. The two *opposite* armature connections form the terminals of one circuit, the other pair those of another independent circuit. The machine is also provided with a commutator for producing direct current as may be desired, specially for exciting the machine. The patentee well recognizes the phase-relations of the two circuits, as well as of the several quadrants of the armature, and the constant nature of the flow of energy which he is thus enabled to obtain from the machine; but he only incidentally mentions its use as a transformer of energy. Yet it is to be noticed that this is a distinct advance over the

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[37] *Proc. I. E. E.*, V. 27, p. 654, Nov. 10, 1898.

[38] No. 390,439, of Oct. 2, 1888. A patent for a three-phase machine (No. 409,450, of Aug. 20, 1889), otherwise identical with this one, was issued to the same inventor on a later application, filed Oct. 20, 1888—after the issue of the Tesla patents.

machine described by Thompson; and as the latter or single-phased device is not claimed by the patentee, it is clear that such a device must have been known before the date of his application, May 9, 1887.

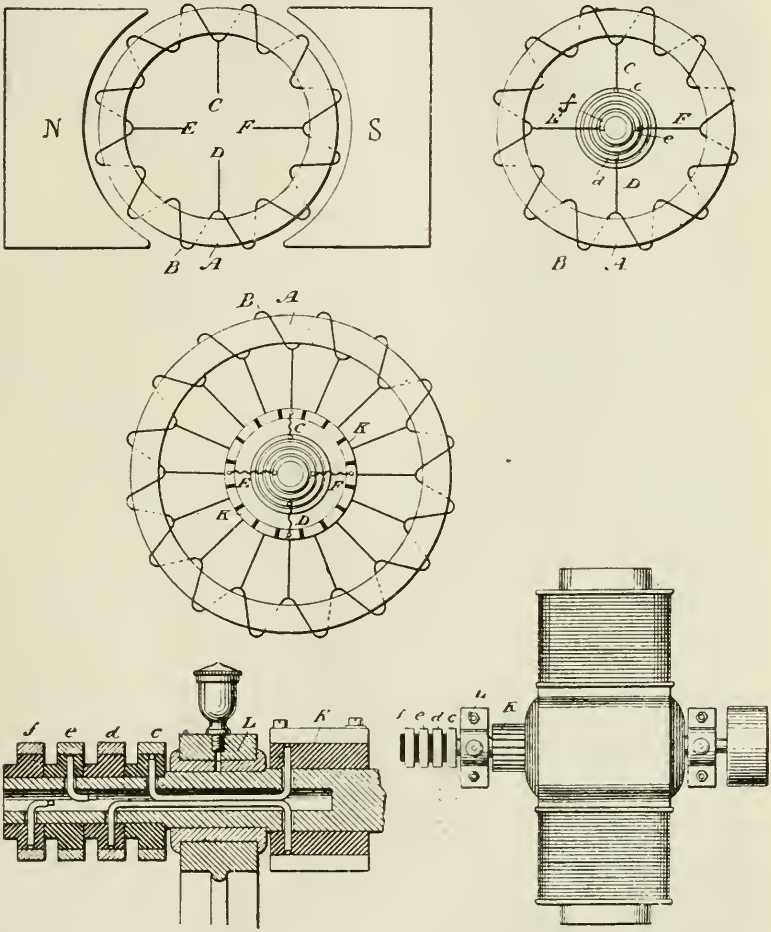

PLATE XVII.—Bradley's single coil rotary transformer. 1888.

Be the question of invention as it may, however, the apparatus was first brought practically and prominently to public notice by the German firm of Schuckert & Co., of Nuremberg, and also by Lahmeyer, at the Frankfort Exhi-

bition of 1891, where they exhibited several large three-phase continuous-current rotaries in actual operation, which attracted universal attention.[39] Since that time the rotary transformer has come into general use.

The rotary transformer being thus in its origin and antecedents a hybrid, cross-bred between two different types of machine whose modes of operation are at variance, we shall not be surprised to find in it some anomalous peculiarities. Like most hybrids, however, it has its uses which neither of its parents can supply.

THEORY OF THE SINGLE-COIL ROTARY TRANSFORMER.

That an alternating current may be obtained from an ordinary closed-coil continuous-current dynamo is not quite so evident as might at first appear; for alternator armatures have been in all cases constructed upon wholly different principles.[40] It is true that it is now commonly said, after the event, that every dynamo is an alternator before the current is commuted; but this statement is not borne out by the facts. If an ordinary closed-coil armature were connected at two diametrically opposite points to collector-rings and rotated in an alternator field of the usual multipolar type, no current of any significance could be obtained; because the positive and negative electromotive forces in each half of the armature would at all times be practically equal. Moreover, a common closed-coil direct-current armature does not produce an alternating current, in the proper sense of the word, nor does such a current exist at any time in any individual coil; for though the electromotive force developed in each coil does or may follow an approximate sine function of the time, the current in the coil remains constant during one-half a revolution, and is then abruptly reversed in direction. This does not happen to all the coils at once, but to each one successively at equal intervals of time; so that, if an alternating current

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[39] Described by W. B. Esson in *Electrical Review* (London), V. 29, p. 529, November 6, 1891.

[40] Thompson, "Dynamo-Electric Machinery," 4th ed., p. 640.

is to be got from such an armature, it must be a new and different current, whether superposed upon it or otherwise independent of it. The principle upon which a true sinusoidal alternating current is obtained from such an armature depends upon the mathematical theorem that the integral of a sinusoidal quantity will give us a sinusoidal quantity; hence, integrating the sinusoidal electromotive forces developed in the individual coils of the armature over any given angle of the same, we obtain a sinusoidal E.M.F. as a resultant. Hence, a sinusoidal form of the current curve requires a sinusoidal space-distribution of the magnetic flux around the armature; whereas, in direct-current working, it is only the total-flux that affects the E.M.F. at the motor-terminals; this, as we shall see, is a matter of considerable importance in the design of single-coil rotaries, as it affects the ratio of the pressure in the two external circuits.

Having obtained a machine which will yield two species of current, it is not difficult to see that we may put in one species to run it as a motor, and take out the other as from a generator. The theory of the machine is not, however, the same in both cases. As a dynamo, the two currents are merely added together or superposed in the armature, whose reactions, resistance losses, etc., are thus, broadly speaking, merely those due to their joint effects. This phase of the problem, more especially with respect to output and armature heating, has been treated mathematically by Woodbridge and Child.[41] But when the machine is used as a transformer, the two currents run, in general, in opposite directions, and must be subtracted; so that the resistance losses in the armature are greatly diminished; or, looking at it in another way, a large part of the current converted either does not pass through the armature at all, or only through a few of its coils. Herein lies the

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[41] *Elec. World*, Vol. 31, pp. 12, 216; January 1st and February 12, 1898. The authors of this article found that, for a *two-phase* and *D C* connection, the output of the machine when generating both kinds of current was actually somewhat greater than when generating only one kind, and the armature heating less for the same output.

great superiority of the one-coil over the two-coil transformer. We lose, however, the advantage of a possible pressure transformation, the ratio of the effective pressures in the two external circuits being substantially fixed for any individual number of phases, or division of the armature.

We may divide our consideration of the one-coil transformer into the following heads: Continuous-alternating and alternating-continuous current working; Phase relations; Pressure relations; Pressure adjustment; Pressure regulation; Current relations; Output; Efficiencies; Hunting; with a brief examination of two-coil theory where it differs materially from that of the one-coil machine.

Continuous-Alternating and Alternating-Continuous Current Working.—Not only is the theory of the machine used as a dynamo different from that as a transformer, but, if one of the two currents be continuous, the case where the latter is the motor or primary is not the same as where it is the generator or secondary current, in that the action of the machine is different in the two cases. While the principles of the dynamotor, as explained on pages 228* ff., apply in a general way here also, especially as regards the self-neutralization of the armature reactions, the introduction of the alternating current upon one side introduces new complications. If the continuous current be on the primary side, the speed of the machine, and hence the frequency of the alternating current produced, naturally depend on the field-excitation and the pressure in the primary circuit, and both will rise and fall together with the latter, as well as with variations in the field-strength. The difference between the primary voltage and the counter-E.M.F. of the machine as a generator, necessary to compensate armature losses and keep the machine running, is accounted for in the secondary circuit by just sufficient phase-lag in the *current*, caused by increased self-induction, to bring the ohmic E.M.F. down to the proper level. This case, then, presents little difficulty, other than the necessity of keeping the speed strictly con-

* March number of this *Journal.*

stant, to preserve a constant frequency of alternation in the secondary circuit.

The case where the continuous current is the secondary, and the primary alternating or polyphase, is somewhat more complex, as it is also much more frequent in practice. This is due to the fact that, whatever the counter-electromotive force produced by the machine and generated in the secondary circuit, the machine must run in synchronism with the primary circuit, or not at all. If, then, so running, this counter-electromotive force is greater or less than that of the primary mains, the current will adjust itself automatically to the proper lead or lag necessary to secure equality of the two, while at the same time the armature currents react upon the field to assist in securing such equality. If the counter-electromotive force of the machine at synchronism is greater than that of the primary circuit, the current will lead, and the reactions will oppose the field; if less, the current will lag, and such reactions will act to increase the field-strength. So far will this action go, that if the load be sufficiently light, the machine will run without field-excitation, by the mere reaction of its armature coils. Thus the machine is to a certain extent self-regulating; but if the lead or lag of the current is unduly increased, the wattless current and armature losses become very large and the effective volts so small that the machine will fall out of step and come to a stop.

It is an interesting fact that all one-coil rotary transformers whose fields are excited from the secondary or direct current winding are self-starting on open secondary circuit. In the case of a polyphase primary, this is due, of course, to the rotary field; but in the case of a monophase primary, to the fact that when starting they act like a direct-current motor in the same case (*i. e.*, when connected in an alternating circuit); the current in fields and commutator being simultaneously reversed, the torque remains constant in one direction; and this condition is maintained until the armature has reached synchronism.

Three-Wire Working.—While, as already pointed out on page 273, two rotary transformers cannot be connected up in

parallel on the primary side, and to a three-wire *D C* system on the secondary side, there is an interesting mode, invented by Dobrowolsky, in which a single rotary transformer can be made to supply both sides of a three-wire system where it has an alternating or polyphase primary. This is done by joining the brushes of the transformer on the secondary side to the outside wires of the three-wire circuit respectively, while the neutral wire is connected to a neutral point on the *primary* side of the transformer, formed by joining each wire of the polyphase circuit thereto through a reactance coil, in star connection. This mode is utilized by Dobrowolsky in the case of an ordinary *D C* dynamo by adding thereto two slip-rings and connecting them by a choke-coil, to the central point of which the neutral wire is attached. It would not seem to be very advantageous where large unbalancing occurs. The current in the neutral is an alternating one having a frequency *n* times that of the primary circuit, where *n* is the number of slip-rings.

Another mode is to wind the machine with two independent coils, each connected to an independent primary (alternating) circuit, and connected in series on the *D C* side, two commutators being required. In the case of a two-phase primary, one coil may be connected to each phase, where the two phases are independent. This was the method employed in the Alioth transformers for Geneva.[42] Of course, this would *not* be a "two-coil transformer," as the term is here used.

Phase-Relations.—The theory of phase-relations in a rotary transformer is very simple and easily understood. It is easily seen that the induced electromotive force in any one portion of the armature winding stands in the same phase-relation to that in any other portion as their angular separation on the ring. This, of course, refers to two-pole machines; for others we need only remember that the pitch of the poles is equal to 180 electrical degrees. Hence, to produce a polyphase winding of any desired number of phases, we naturally divide the armature into the same number of

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[42] *Electrician* (London), V. 38, p. 340, January 8, 1897.

symmetrical portions and connect a slip-ring to each point of division.

It is here to be noted, however, that portions of the armature in opposite phase, that is to say, on opposite sides of the armature, cannot, as in ordinary polyphase generators, be connected in series to increase the generated E.M.F. and lessen the number of leading-in wires, because this would result in short-circuiting the intermediate portions of the armature; in other words, we cannot treat the several circuits as independent. This is a point of great importance, especially in connection with three-phase circuits, because, as originally pointed out by Mershon [43] and later calculated by Kapp,[44] the output of the machine is very largely increased in proportion as we increase the number of phases. So that, in dividing the armature into *six* instead of *three* parts, we must simultaneously double the number of our slip-rings and the number of leading-in wires. This is accomplished by Mershon [45] without unnecessarily doubling the number of conductors in the transmission line, by simply keeping the three-phase secondary circuits of the static step-down transformer, at the delivery end, separate, so as to obtain three independent circuits, whose electrodes are accordingly introduced at respectively opposite points of the armature, just as in two-phase machines. In other words, with the closed-coil armature, the mesh-connection is the only one possible; and we should, in speaking of phases, consider the number of phases the same as the number of parts or segments into which the armature is divided. From this point of view, the ordinary monophase would be called a "two-phase," the ordinary two-phase a "four-phase," and the six-wire three-phase a "six-phase" connection; and to avoid ambiguity we shall retain this terminology. The angular displacement between the different phases is then in all cases the quotient of the circumference by the number of phases; thus, three phases are in

[43] *Elec. World*, V. 25, p. 684, 1895.
[44] *Elektrotech. Zeitsch.*, V. 19, p. 621, Sept. 15, 22, 29, 1898.
[45] Patent No. 556,359, of March 17, 1896.

ternature, four phases in quadrature, six phases in sexature, etc.

We should observe also that where the number of armature phases is even, so that there are two segments in opposite phase, and two slip-ring connections at an interval of 180°, there are two modes of connection of the external circuits, and two corresponding modes of dealing with the machine mathematically; that is to say, we may either form a separate circuit of each pair of adjacent armature connections right around the ring, and so form as many different circuits as there are slip-rings, or we may connect together each opposite pair of armature connections, and so form half that number. Similarly, we may consider the current in each segment as single, or as the result of several superposed two-phase (monophase) currents, formed by the latter mode of connection.

[*To be continued.*]

ELECTRICAL SECTION.

Stated Meeting, held Tuesday, April 10, 1900.

APPARATUS FOR POWER DISTRIBUTION FROM CENTRAL STATIONS.

By Charles F. Scott,
Chief Electrician, Westinghouse Electric and Manufacturing Company.

The recent tendency in the commercial and industrial world is toward combination and concentration. Many small companies and many small factories are placed under one management, with gains in economy and efficiency. The combinations of capital have united many formerly competing electric companies and have thereby rendered it not only possible, but also imperative that the engineer shall bring the various generating stations and distributing systems into a single and comprehensive unit. Moreover, new enterprises dependent upon electrical operation are constantly being projected which far surpass prior undertakings in their magnitude and importance. The develop-

ment in the various machinery, apparatus and appliances which has recently taken place affords the means by which these large undertakings may be carried out.

It is not the purpose of the present paper to enter very far into the general engineering problems which present themselves in connection with modern central station practice, such as the arrangements with respect to the steam plant, the determination of the size of the units to be employed, the location of sub-stations and the various considerations which concern the conductors for the transmission and the distribution of current. It is, however, proposed to consider the various types of electrical machinery which are involved in a general system, including particularly generators, rotary converters and motors, and to show some recent types of construction and indicate some of the characteristics of their performance, particularly those of especial interest or importance.

DIRECT CURRENT AND ALTERNATING CURRENT.

A dozen years ago there was a bitter controversy in the field of central station engineering. On the one hand was the direct current system distributing at 220 volts with a middle or neutral wire; on the other hand was the alternating current system distributing at 1,000 or 2,000 volts with lowering transformers. One was well established, was simple and readily comprehended; the other was new, the principles of its operation were apparently abstruse and were not generally understood. Moreover, various dangers, real and imaginary, were attributed to the alternating current, and its possible usefulness was greatly limited because there was no suitable motor for power service.

The alternating current, however, continued to exist and has shown a remarkable development during the past ten years. It and the direct current have occupied fairly well defined fields. The direct current has usually been employed in central station work in the centers of cities where a very large volume of current is supplied within a comparatively short radius. The alternating current has found favor in towns and smaller cities where the service

is more widely distributed, and also in the outlying portions of cities which have a direct current system in the central portions. In a notable number of cases the alternating current has also been used throughout a city and has therefore monopolized the whole field. It can of course be used in the consumption circuits with especial propriety where the power is received in the form of alternating current over a transmission circuit from a distant water power.

During the past few years central station engineers have been encountering new problems which have, in a measure, brought to life the old controversy between the direct current and the alternating current, although in a different form. The magnitude of electrical work, the areas which must now be covered, the economies which are necessary in the generation of current and its distribution, bring new requirements. The wilderness of shafting, pulleys, belts and high-speed machines which did service some years ago has given place to stations with large direct-connected units; but even these are now becoming inadequate in stations for the generation of direct current for several reasons. The limited area over which current at low voltage can be distributed without undue cost for conductors makes it necessary to place the station at the center of the district to be supplied, and if this area exceeds a few square miles, it is necessary to erect additional stations. The supply of current to a large area therefore comes from a number of stations, and the economies of a large generating plant are not secured. Moreover, as these central stations should be located near the centers of their respective areas, they will usually be found in districts where real estate is expensive and where there is not the advantage of cheap transportation of coal and ashes which might be secured if the location of the station were selected with respect to its own specific function of generating current cheaply, and not on account of the necessities of the distributing system.

The direct current system has been forced to find a means by which the generating station can be advantageously located and the distribution of the direct current can be made from a large number of centers. The problem here

involved is one of voltage or pressure. For economic transmission over a considerable distance the pressure must be high in order that the current may be low and the size of the conductor small. On the other hand, for distribution in the consumption circuits the pressure must be low in order that it may be safe and adapted for lamps and motors. These relations are so well understood that it is needless to enlarge upon them. The cost of copper is, however, but one element, for cost of the insulation and lead covering of cables and the ducts for underground service make high voltage all the more imperative.

The requirement of the general system just outlined is that the current from the generating station shall be transmitted at high voltage through small conductors to various sub-stations or distributing centers, where the electrical energy shall be suitably transformed to a low pressure and an increased current.

There is no feasible and practical method by which direct current can be transmitted at a high pressure and reduced at sub stations to a low pressure.

The alternating current, however, through the medium of the transformer can be varied in voltage, either increased or reduced at will in apparatus of almost ideal simplicity, without moving parts, with little deterioration and at a remarkably high efficiency. The direct current engineer has been forced to adopt the alternating current as a part of the general system and to generate and transmit current to various sub-stations as alternating current and then to convert it into direct current. This is now being done in many plants, both for supplying current at 220 volts, and also for supplying current at 500 volts for the operation of railways. In many cases where no general comprehensive system has been adopted, the alternating current has been used as an auxiliary, so that the various steam stations in a city have their capacity augmented by the supply of alternating current.

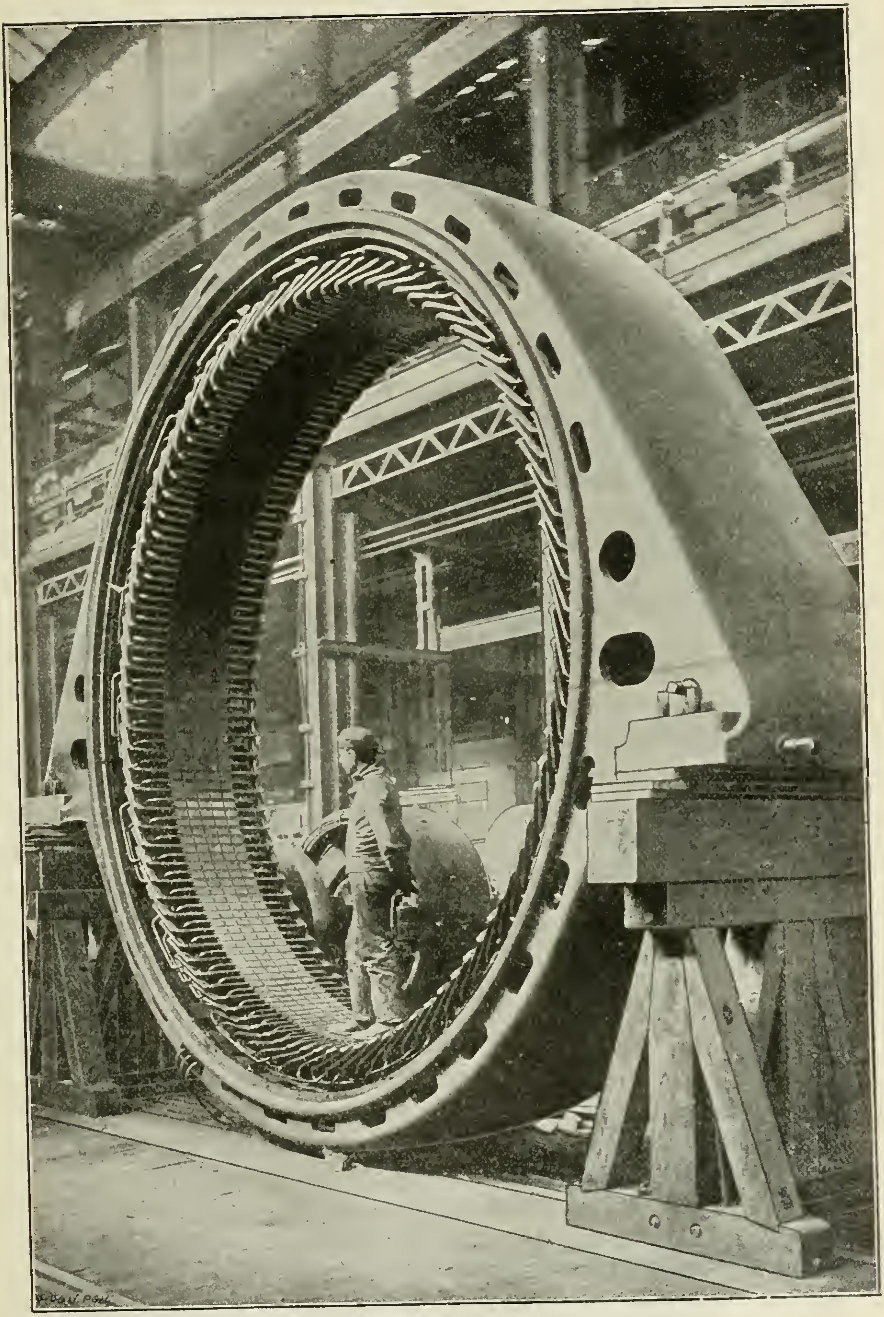
Even this relation between the direct current and the alternating current cannot be accepted as a final one, and as the best for universal adoption. The question naturally

arises as to the necessity or desirability of making the conversion from alternating to direct current. If all the current which is generated is alternating, it should certainly be retained as alternating current and distributed and used in this form if it is possible, and thus avoid incurring the loss in energy and the cost of apparatus and the attendance necessary for converting it into direct current.

THE ALTERNATOR.

The alternator of ten or twelve years ago, with its high-speed armature, with a surface winding held in place by treacherous band wires, would hardly be recognized as belonging to the same class of apparatus as the modern engine-type alternator. Belt and pulley have been discarded and the engine supplies the shaft and bearings. In many large machines the revolving armature has given place to a revolving field, which is constructed to have mechanical safety comparable with that of a fly-wheel, and in fact to perform the mechanical functions of a fly-wheel, thereby placing the fly-wheel exactly where it is required, without the strains which would otherwise come upon an intervening shaft. The stationary armature winding is laid in grooves or slots; it is not the hand winding of the olden time, but a succession of coils wound to exact dimensions on a lathe and insulated before being put in place, or else a succession of straight bars which can be shoved endwise into partially closed slots and joined at the ends by connectors of copper strap.

The most striking feature of the field is its simplicity and the excellence of its mechanical construction. In the construction employed by the Westinghouse Company a central spider of cast iron is surrounded by a ring of laminated soft steel plates. These plates are punched into sections 2 or 3 feet long, which include two pole pieces. The sections have projections upon their inner sides which fit accurately in dovetailed slots in the surface of the spider; the sections are built up overlapping so as to break joints, and when the laminated plates are built up to the proper thickness they are clamped together, a large



Stationary armature for 750 k. w. alternator.

number of bolts running through from end to end. The friction between the surfaces of the thin plates as well as the bolts through the holes gives a most substantial construction; the field is, in fact, a steel rimmed fly-wheel. The field coils are made of copper strap approximately $\frac{1}{16}$ inch thick by $1\frac{1}{2}$ inches in width, wound on edge, forming a single layer. The turns are then separated by asbestos soaked in shellac, and the whole coil is then baked, forming a solid and complete whole. These are placed over the field poles and are held in place by copper or brass wedges, which are in turn held by being placed in grooves along the sides of the projecting poles.

The stationary armature consists of a laminated ring which is surrounded by a cast-iron frame or yoke. The laminated plates are also provided with teeth and slots which form grooves along the surface of the armature suitable for receiving the conductors.

The number of slots in which the winding is placed has an important bearing upon the electrical performance of the alternator. A common form of alternator which immediately succeeded the old surface-wound armature was provided with a number of teeth equal to the number of field poles. A coil was placed around each tooth and a single-phase current was generated. The number of slots may be increased, so that instead of having a single coil for each field pole there will be several coils occupying the several slots, so that the resultant action will be produced by a number of coils coming under the action of a field pole at successive moments. The various turns in a coil are in this way separated into different slots, instead of occupying a common slot. It is well known that the self-induction of a number of turns of wire is much less if these turns are not placed close together in a common coil, but are separated and form several separate coils. It is also well known that the self-induction in an armature is a very important element in the voltage regulation of an alternator. For example, the voltage of a toothed armature in which there is high self-induction falls very considerably when a load is thrown upon the alternator, while there is comparatively

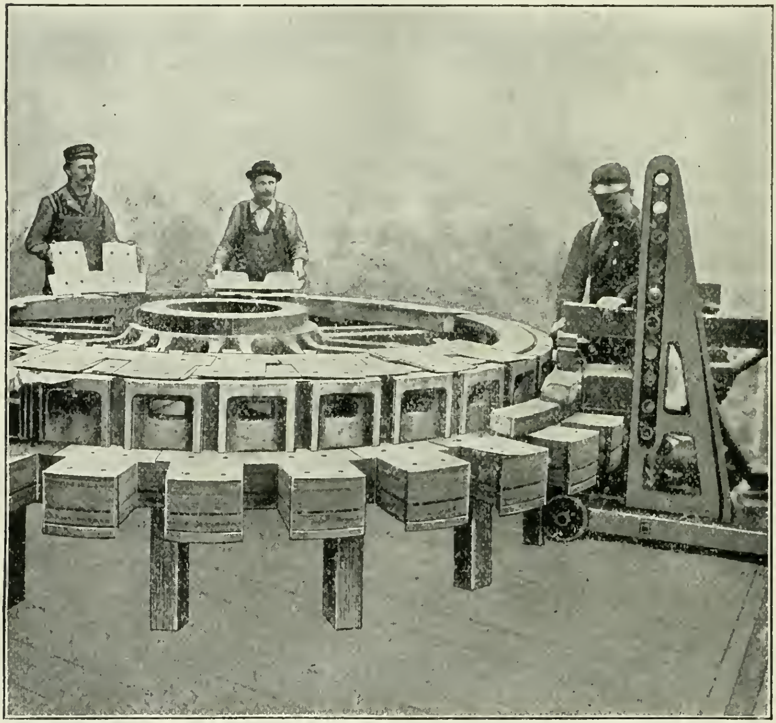
little decrease in voltage when load is thrown upon an alternator of similar proportions, except that the armature winding is placed in many slots. This difference in regulation is very marked when the alternator supplies current which is out of phase with the E.M.F. On this account, toothed armatures, which were quite satisfactory for carrying a load of incandescent lights, in which the current is in phase with the E.M.F. and which was subject to fairly slow and gradual changes in load as lights were turned on or off, is not admissible in power service, where the character of the current, frequently being out of phase with the E.M.F., is such as to produce a greater drop in voltage and in which the load is apt to be variable and to fluctuate over wide limits. While the number of slots in an armature is not the only element determining the regulation, yet it is a very important one, and in general an alternator with few slots per pole may be depended upon to regulate poorly, while one with many slots will in general give good regulation.

Excellent regulation is desirable, not only in order that a satisfactory service may be delivered to a fluctuating load, but also in order to insure favorable conditions for the parallel running of alternators, and in general for rotary converters or other apparatus connected with the system.

PARALLEL OPERATION OF ALTERNATORS.

The problem of parallel running is one which has recently come into prominence, because it has become a necessity in the operation of large power stations. This problem has been considered from a number of standpoints. The electrical conditions, including the various proportions of the alternators, such as their self-induction and their field reaction, the flow of idle or wattless current between the armatures, the relative field strengths, are all elements which have received more or less consideration and sometimes prolonged discussion. The speed of the engines, not only the mean or average speed, but the variation in speed during a revolution, also the weight of fly-wheel, are elements to which attention has been quite properly directed.

I purpose, however, considering the problem from a little different standpoint from those mentioned and not take up alone the voltage or current or speed, but to go at once to that fundamental element for which everything else exists, namely, the power. We will for the present omit the functions of the system other than its function of receiving



Building up the laminated pole pieces for a revolving field alternator.

power from two or more prime movers and delivering it to a common circuit.

We will assume two similar engines carrying similar alternators upon their extended shafts which are connected to common bus-bars and supply an outgoing circuit.

We will also assume two similar engines carrying similar gear wheels upon their extended shafts which drive pinions upon a common shaft which supplies power to an outgoing

belt. The number of teeth in the gear wheels may be taken as equal to the number of poles on the alternator.

There is a certain elasticity in the electrical connection between two alternators which allows a relative displacement between the angular position of the two armature windings with respect to the field poles without injury, provided the displacement does not become too great. When there is a displacement there is a flow of current between the two armatures tending to pull them to a common position, and this force is proportional to the angular displacement. In the same way we may imagine the spokes of the gear wheels to be slightly elastic, thereby permitting a deflection amounting to a fraction of the pitch between two teeth. It is not necessary, therefore, that the two engine shafts occupy exactly the same angular position, but one may be slightly in advance or behind the other. The forces exerted by the two engines upon the countershaft will be different and there will be a force tending to a common position of the two quite similar to that in the electrical system.

The proper condition for connecting the second engine to the common shaft by means of the gear wheel when the first is running is obvious. The pinion should not be thrown into the gear wheel unless the engine has the proper speed and the proper angular position. If the speed of the two engines is not the same just before they are connected together, there will evidently be a severe stress exerted during the extremely short time in which it is necessary to impart the necessary energy to the fly-wheel and other moving parts of the slower engine in order to bring it to the proper speed. A difference in speed of 1 per cent. may involve very great stresses, as the speed must be equalized almost instantly. It is also evident that if the arrangement is such that the pinion and gear-wheel can be instantly forced together when the teeth have not the proper angular position the result will be in the nature of a blow in order to secure the proper angular position.

The corresponding conditions in the electrical system are also quite evident. If engines and generators are not

running at the proper speeds or have not the proper angular positions at the time that they are thrown together, very great stresses will be brought upon the electrical system in order to produce the proper speeds and positions almost instantly.

When the two engines are connected by gearing they must of course run at identical speeds. This is true not only in respect to the total number of revolutions per minute and to the time of a complete revolution, but the angular speeds during each revolution must be identical, except in so far as the angular positions may change on account of the flexible spokes with which the gear wheels are supposed to be provided. If an engine running alone were to vary in angular velocity during a revolution, then there would be no marked effect unless the variation were quite considerable. For example, if the engine drives the shafting of a mill, the speed would fluctuate slightly; if it drives a dynamo, the voltage delivered would vary with each revolution, but would hardly be noticeable unless the variation were sufficient to produce a fluctuation in the lights which may be supplied. In each case the engine would deliver power at a very nearly uniform rate throughout the revolution. But when two such engines are connected by gearing and one tends to be in advance of the mean position when the other is lagging behind, then they cannot deliver practically constant power throughout the revolution, for the leading machine will tend to carry the greater part of the load, and if the natural fluctuation in speed is sufficient it may even take the whole load. When a part of a revolution is passed the conditions have changed and the second engine takes the undue proportion of the load. If the two engines were belted to a common shaft, the stretching and slipping of the belt would aid the equalization of the load so that each engine might be carrying a very nearly constant load.

In the electrical system the analogy is obvious. There will be a corresponding shifting of load from one outfit to the other, similar to that which occurred when the engines were connected by gearing instead of by alternators. If the

electrical connection were made not by alternators but by direct current machines, in which there is no requirement as to relative angular position, then each engine and generator would carry very nearly constant load throughout the revolution.

The above considerations indicate that engines for parallel running must be such that when running alone the angular displacement from perfectly uniform rotation must not exceed certain reasonable limits. These limits are determined by the number of poles in the alternator or the number of teeth in the gear and also the angular displacement which may occur without introducing undue stresses in the connecting system, *i. e.*, the current between the alternators in one case and deflection of the steel spokes of the gear wheels in the other case must not be excessive.

The gear wheel in one arrangement and the alternator in the other are simply means for transmitting the power developed by the engine. It is essential to keep this simple proposition clearly in mind, as it is sometimes imagined that the power in the electrical system can be regulated or controlled by means of the electrical adjustments of the alternators. In cases where this may be effected, it is because some new adjustment of the engine governing apparatus has been caused thereby, which in turn results in a change of the power developed by the engine. The alternator, like the gear wheel, simply transmits the power received from the engine. The power developed by an engine is primarily due to the adjustment of its valves. The valves, valve gearing and the governor must necessarily be looked to as quite important in parallel operation. The requirements upon these elements for parallel running are considerably different from those in other service.

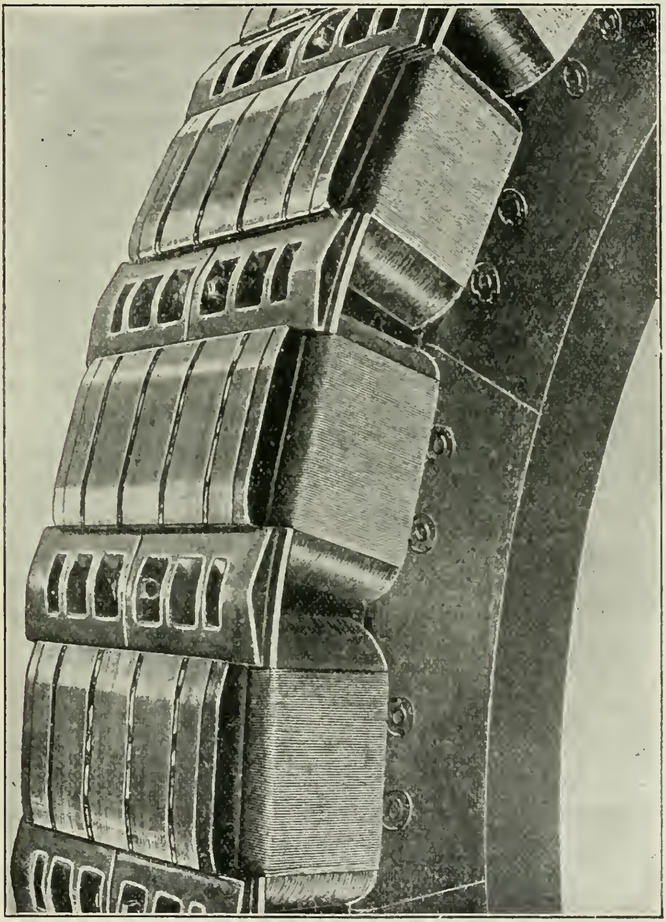
Proper division of load between engines operating in multiple must therefore be effected by the governing mechanism. It is sometimes supposed that engines will be well adapted for parallel operation if they do not vary in speed between no load and full load more than say 1 per cent. Close speed regulation may be quite unsuited for parallel running. Thus, if one engine falls from 100 revo-

lutions to 99 revolutions per minute when loaded, and a second engine has the same excellence of regulation, but happens to have a speed falling from 100·5 to 99·5 revolutions, then it is obvious that when running at 99·5 revolutions one engine would be adapted for carrying half load and the other for carrying full load. A difference of only ½ per cent. in the natural speed of such engines may tend to a very unequal distribution of load. On the other hand, if each engine falls off 4 or 5 per cent. between no load and full load, a difference of ½ per cent. or 1 per cent. in their absolute speeds for a given load would cause only a trifling difference in the loads which they would carry when operating at equal speeds. It has been found in practice that usually much more satisfactory results are obtained when the speed falls off considerably, and that from 3 or 4 to 5 or 6 per cent. is desirable for good operation.

In considering the effect of fluctuation of angular velocity it was found that the load may rapidly shift from one engine to the other, due to the fact that the speeds must be maintained practically identical, although the natural tendency of the engines may be to produce fluctuating speeds. One engine is momentarily relieved of a part of its load; the ordinary requirement is a readjustment of the governor. The governor mechanism may therefore change its position to give a decreased admission of steam. A moment later the conditions are reversed and the engine takes more than its share of the load, thereby tending to give a different adjustment to the governor. The effects of angular fluctuation, however, are necessarily small and rapid and are not so apt to produce instability in the governing mechanism as certain other causes which may exist even though the engines have so uniform a turning effort and fly-wheels of so great weight that the fluctuation in angular velocity is inappreciable.

Two engines may be delivering equal power to a constant load either through gear wheels or alternators. The load may be suddenly changed. The change in load, either through a momentary increase of speed or other action upon the governors, causes them to act and readjust

the valves. When an engine running singly has a change in its load, the governor changes, often going beyond the required position, then returning a little too far, and after several oscillations settling to the proper position. The



Portion of a rotating field showing coils in place.

engine during this time is carrying its new load constantly and seeking to adjust itself to this new load. When two outfits are running in parallel and two governors are simultaneously seeking the new position required by

change in load, it is easy to see how neither governor is left free to find its new position (as it would be if the engine were running singly), because the load may be continuously shifting from one engine to the other. The two governors will have a mutual effect upon each other, as the load on each engine is not constant, but is partly dependent upon the governor of the other engine. If therefore the governors are oscillating back and forth about a mean position, it is easy to see how this oscillation may increase in amount. If one governor has moved beyond the proper position and is admitting too little steam, it should then readjust itself for the proper load. But at the same moment the other governor may be in a position which admits too much steam, thereby causing its engine to deliver too much power and thus carry load which should be carried by the first engine. The governor of the first engine, which is already carrying less than the proper amount, may, on account of the decreased load, seek to adjust itself for still less load. This causes a still wider divergence between the two governors, and presently they may both tend to swing back and pass the mean position. The interaction of the governors may thus continue and increase in amplitude until the shifting load from one engine to the other, caused by oscillation in the governor mechanism, may be far beyond permissible limits.

It will be well to consider the conditions which prevail when alternators are driven by water-wheels, where, as it is well known, parallel running is comparatively easy. Water-wheels in general give uniform rotation without the angular fluctuations which occur in steam engines having reciprocating parts and an intermittent admission of steam. The speed regulation of water-wheels is comparatively poor, and the governors are comparatively slow in action. A load gradually applied may make little change in speed, whereas, a suddenly applied load may cause a momentary decrease in speed which will be quickly recovered.

The governor of the steam engine is often prevented from oscillating by making it sluggish in action by the use of a dash-pot. The dash-pot must allow the freedom of

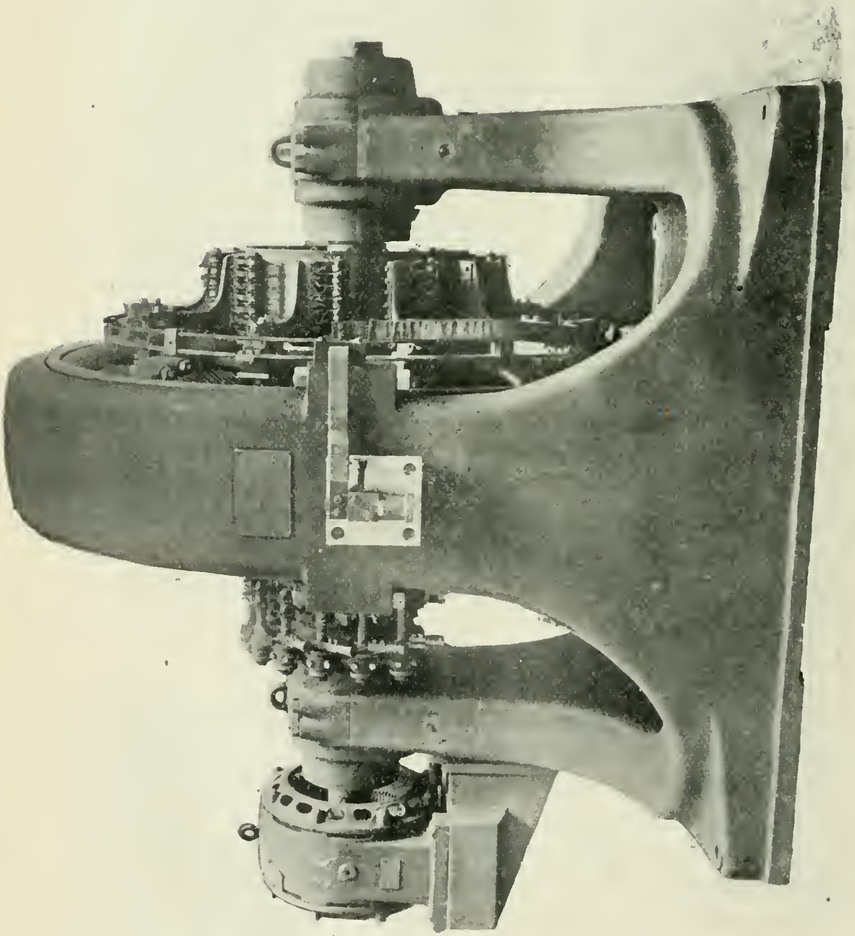
motion essential for regulation under changing load, and yet destroy the delicacy and sensitiveness which produce oscillation and hunting.

Several points in parallel running which are common both to alternators and to gear wheels have been considered. There are some elements in alternators which are not common to gear wheels. These have to do with the E.M.F.'s and the currents rather than with the power. If the wave forms of the two alternators are not similar, but sometimes one and sometimes the other E.M.F. during each cycle is higher, there will be a local flow of current between the two armatures. Again, if the field currents are not equal, the E.M.F.'s would also be unequal if the generators were running separately; but if the armatures are connected with a common bus-bar, the E.M.F.'s are necessarily equal and an armature current circulates between the two machines which equalizes the induction in the two machines, as the phase of the current is such that it assists the weaker field current of one machine and opposes the stronger field current of the other machine. This is a so-called "wattless" current; its function, like that of the field current, is for magnetizing, and it does not transfer power. It therefore has no mechanical analogue in the gear wheels and is not an element with which the engine need concern itself.

THE ROTARY CONVERTER.

The rotary converter is a machine of very considerable interest, as it has only recently entered the commercial field, and as it proves to be of so great importance in linking the alternating and direct current systems, as well as presenting many features of engineering interest. The machine combines the function of alternating current motor and direct current generator. The same armature and the same winding are used in both functions, thereby not only combining two armatures into one, but combining them in such a way that an armature of given size has a greater output as a rotary converter than it would have either as a motor or a generator. The common facts regarding the

rotary are well known; thus, the alternating current may be introduced as 2-phase or 3-phase; there is a definite ratio between the alternating E.M.F. and that delivered by the

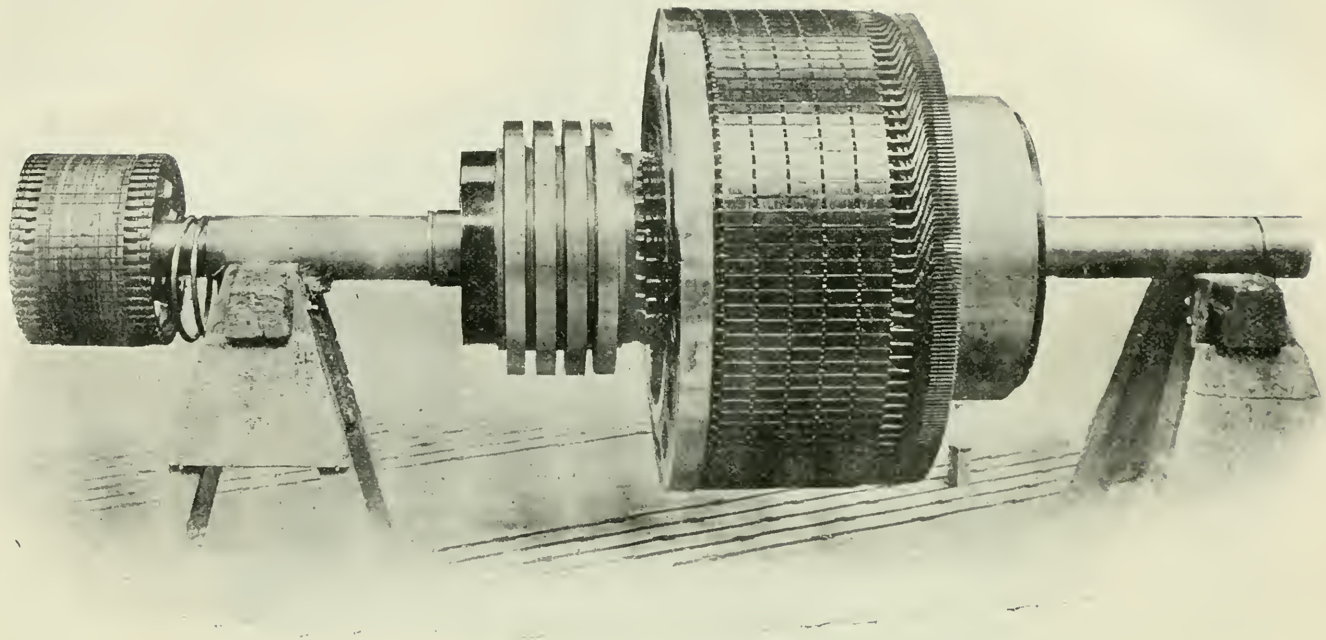


Rotary converter complete with starting motor.

commutator; the E.M.F. of the direct current may be varied by any suitable form of alternating current regulator; a middle wire carried from the secondaries of the lowering

transformers may enable a 220-volt rotary with two sets of brushes to be used for supplying a 3-wire distributing system; the machine may be used in conjunction with the storage battery; it is capable of very great overloads and is eminently suited for the variable demands of railway service.

It is, however, when we come to consider the rotary converter as a part of a working system that features of particular engineering interest appear. The converter must run as a synchronous motor, and many of the conditions which pertain to the parallel operation of generators apply also to the running of the rotary. The manner of connecting it to the circuit when it is started by a separate motor, or by a direct current to its own commutator, is similar to the connection of an alternator to the bus-bars in that the machine to be connected must have the proper speed, the proper phase relation and the proper E.M.F. before the switch is closed. The armature of the converter by its inertia tends to run at a uniform speed. If the speed of the generator is fluctuating, then the armature of the converter will attempt to follow that of the generator and will be successively accelerated and retarded. If the armature of the converter were without weight, it would be free to follow the fluctuations, but as that is not the case, it cannot fluctuate exactly with the generator armature and its inertia will cause it to lag behind the position of the generator armature. At a given moment the armature of the converter may be retarded and running below the mean speed. It will tend to continue at this speed until the generator speed has increased and supplies the necessary energy for quickly accelerating the speed of the rotary. A slight change in the angular velocity of an engine during each revolution therefore tends to cause corresponding fluctuations in the speed of the converter which demands that the flow of energy to the converter be intermittent as its armature acts as a fly-wheel. This increases the current to the converter, and as its armature cannot follow simultaneously the angular positions of the generator armature, it is sometimes in advance and sometimes behind the proper position



Armature of rotary converter.

for commutation, thereby tending to cause sparking or flashing at the brushes.

The converter does not take kindly to these fluctuations and treat them passively. It has a freedom of action of its own. When the generator attempts to force the armature to oscillate rapidly by the mean position there are various reactions within the converter which may respond to the tendency to vibrate or oscillate, and the armature may act as a pendulum and increase its amplitude of vibration. As the result, each oscillation may be a little greater than the one preceding, so that each time the armature falls behind or advances beyond the mean position it is a little further than before, until stable conditions are reached and it continues to vibrate through a fixed arc, or until the amplitude is so great that the armature is no longer able to remain in synchronism.

A means of preventing hunting which has proven to be very effective utilizes a very simple principle, namely, that of introducing a resistance to the oscillation of the armature, and thereby preventing the wide fluctuation in the same way that a dash-pot tends to prevent ordinary mechanical oscillation. The current in the armature produces a comparatively slight magnetic field which is stationary with respect to the field poles when the armature rotates synchronously, but when the armature oscillates back and forth, thus being alternately generator and motor, the armature current causes a varying field, which induces currents in the faces of the field poles which hinder the oscillation of the armature. If there are other metal parts near the armature surface, such as brass or copper bobbins for the field coils, currents may be induced in them. An efficient form is a copper shield around the field pole near its face, and extending over the face of the pole along the sides. The shields act as an electric damper whenever the armature begins to oscillate.

The converter will be much freer to set up oscillation if the force tending to hold its armature in close accord with that of the generator is comparatively weak. The force is smaller when the regulation of the generator is poor, and

the electrical connection between generator and rotary is much more rigid when the generator regulates well. The angular displacement between the position of the two armatures will be accompanied by a comparatively large current from the generator of good regulation, which will tend to prevent the fluctuations of the rotary.

From the above considerations it is clear that alternators driven by belt or by water-wheels tend to give more favorable conditions than those directly connected to engines for driving generators which supply current to rotary converters, as the angular speed will usually have greater regularity. Other rotary converters and synchronous motors, as they are generators of E.M.F. in common with the alternators, may become disturbing elements, and a converter which may run smoothly under other conditions may behave very badly when a synchronous motor or another converter connected to the circuit at some distant point is not operating properly. This is, however, not true of induction motors. They have an opposite effect, and their presence on a system facilitates the operation of the rotary and also the parallel running of the generators.

ALTERNATING CURRENT MOTORS.

The power service of a central station is of great and increasing importance. For railway work the direct current motor is used, and choice must be made between a number of stations generating direct current at 550 volts or a large alternating current power station, with sub-stations for converting to direct current. The latter method has been adopted in New York City, where large plants are now being installed.

For general power service, in which stationary motors are used, both direct current motors and alternating current motors are available. The direct current motor is well known, and places a high standard of excellence for its rival to equal or surpass.

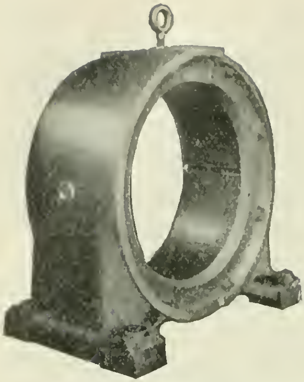
The alternating current motor is not so well known, and the theoretical explanations and formulæ by which it is often elucidated only make it more vague to many minds.

The old controversy of induction *vs.* synchronous motors is solving itself. There are few, if any, who seriously advocate synchronous motors of very small size, say below 50 or 75 horse-power. In larger sizes the induction motor has been growing in favor until it is quite generally preferred up to several hundred horse-power, although there still exists a difference of opinion regarding very large sizes.

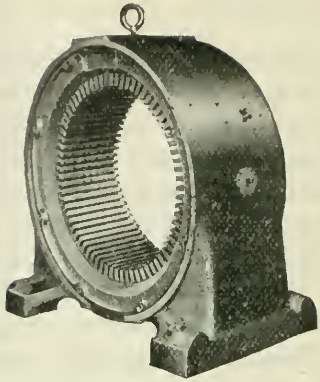
It is quite probable, however, that the synchronous motor will not be wholly displaced, for there are a few cases in which some of the peculiar features of the synchronous motor are so useful as to more than compensate for the increased mechanical and electrical complication, the greater difficulty in operation, the increased liability to interruption of service and the many injurious effects which it is capable of producing upon the system.

The induction motor, the form which is the one in common use for general power purposes, is unique in its mechanical simplicity. However confusing the theory may be, dealing with difference of phase, wattless currents, shifting fields, mutual induction, magnetic leakages and power factors, it is mechanically simple. But these theoretical features do not interest the customer any more than the thermodynamic principles and the heat cycle of a gas engine concern the man who wants it to run his printing press.

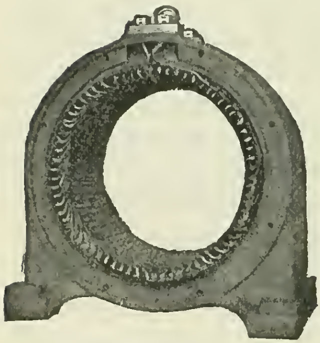
The accompanying illustrations show the form known as the Westinghouse Type "C" Motor, which is widely used. The cylindrical cast-iron frame carries an inner cylinder built up of rings of laminated iron. The slots along the inner surface contain coils of wire, which constitute the primary winding which is connected to the supply circuit. The rotating element has a large number of slots, partially closed at the top, containing copper rods or bars which are slipped in endwise. These bars are securely bolted at each end to a substantial metal ring. It is all so exceedingly simple that one must appeal to negatives to describe it and infer what it is by telling what it is not. It has no commutator, no brushes, no moving nor sliding contacts of any kind; there is no mechanical friction nor wear, except in the self-



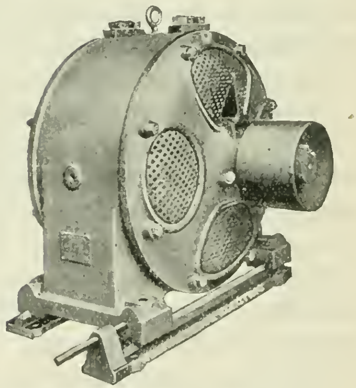
Cast-iron housing.



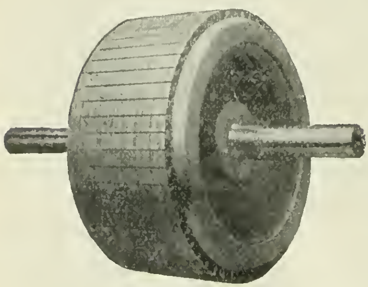
Primary ready for winding.



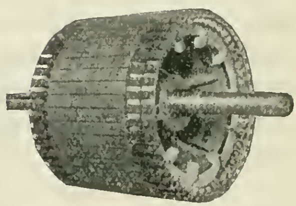
Primary completely wound.



Type "C" motor complete.



Secondary core.



Secondary complete.

CONSTRUCTION OF A TYPICAL INDUCTION MOTOR.

oiling bearings in which the shaft runs; there are no band wires, no delicate windings, no vital parts to be weakened or thrown off by centrifugal force. It is the presence of these things which makes necessary a large proportion of the cost of repairs and renewals and causes directly or indirectly most of the accidents and burn-outs which are incident to direct current motors. It is the absence of these things which makes the Type "C" motor the most nearly perfect mechanical form of motor which has been devised.

In electrical characteristics the induction motor and the direct current motor present some marked differences. In some features one, and in some features the other excels. A fair comparison must not be limited to a single element. The induction motor is not to be fairly judged by considering only its efficiency, or its power factor, or its starting torque, or its starting current, or its speed regulation, or its overload capacity. Nor is this all; it is not merely efficiency in power, but effectiveness in service; not electrical excellence, but mechanical reliability which is of first importance, particularly when motors are to be distributed broadcast in cellars, restaurants, offices, shops and factories, consigned to the tender mercies of janitors and office boys. The delay resulting from an accident to a motor in a machine shop or a printing office may cost as much as the motor itself or the power required to run it a year.

Although electrical performance is not the principal element in a choice between the direct current and the alternating current motor, yet it is important. The full load efficiencies of commercial motors are fairly equal, but at small loads the induction motor has a higher efficiency, notably in the small sizes where the brush friction of direct current motors is relatively high.

The induction motor is admirably adapted for meeting emergency conditions, not only on account of its mechanical construction and absence of commutator, but also on account of its electrical characteristics. It may carry an overload of two or three times its normal load for a short time without injury, and in case of accident, in which the motor is overloaded and brought to rest, no damage will occur for a

few moments, not until the motor becomes overheated. The current to the motor at rest is limited by its self-induction. Under similar circumstances a direct current motor would take an enormously great current (unless the current is automatically interrupted) and damage would result immediately. If for any reason the voltage be lowered or even interrupted for a moment, the induction motor will decrease in speed momentarily, but may continue its work without stopping, or, if it should come to rest, it may immediately start when the current is again supplied. This feature has proved to be of very great advantage in some important installations. Under similar conditions with most direct current motors the services of an attendant would be required for starting. The induction motor of the forms we are considering is ideal in that it admits of no adjustments nor tampering by the ignorant or curious. There are no brushes nor field rheostat to adjust, and the starting device, even if it be improperly set, will only cause the motors to start with greater current than would otherwise result, whereas a similar mistake with other motors might prove disastrous.

The speed of the induction motor has a perfectly definite limit within a few per cent. of its ordinary running speed; no accident can cause it to be higher. It is not uncommon for a failure in the field of a direct current motor to result in a high armature speed, which brings very serious results.

THE CENTRAL STATION OF THE FUTURE.

The progress in central station engineering indicates that the various characteristics of the alternating current which make it adapted to the generation and distribution of electric energy have caused it to be recognized and adopted, so that we may look to the alternator as the form of generator which will be used in the future central station. When, however, we reach the consumption circuits, we find a divergence of practice, for the alternating current and the direct current are both adapted for this service. Each has its own particular characteristics and types of apparatus, each has its particular points of merit, and each has points in which it is not so good as the other. The

alternating current, however, possesses certain fundamental advantages, such as reduced cost for transforming apparatus, both in original investment and in attendance, reduced cost of conductors as the distributing system is supplied from numerous widely distributed transformers instead of being supplied from sub-stations, increased efficiency, and an ideally simple motor. The item of conductors for the distributing circuits becomes of very great importance where the conductors must be placed underground, and the cost of the copper alone may be small compared with the cost of the ducts or conduits in which the conductors are placed. Such items as these differ so widely in different cases that no general statement as to relative values can be made, but each case requires special consideration.

A peculiar difficulty confronts the engineer at the present time which makes the problem a double one. It is necessary on the one hand to utilize as far as possible the apparatus which now exists. This sometimes means the coöperation in one general system of many stations which were once entirely independent, each with its own particular class of apparatus and distributing circuits. This in itself is no easy task, but it is not sufficient to simply attain present results. There should be a plan which will lead to the ultimate system which will be the best. If apparatus is employed which is less efficient, more complicated and less reliable than other apparatus, it is usually simply a question of time when the change must be made from one to the other. It is obvious that the system and the apparatus which is most simple and reliable in its operation is that which will probably be adopted ultimately. The alternating system, therefore, has naturally the first claim to consideration, and upon the broad principles of simplicity it is the one which has the first place, and the burden of proof lies with the direct current to show adequate compensation for the cost and complication which its introduction involves.

We have considered the central station almost entirely with respect to the methods and the apparatus by which the energy of the engine is distributed for various industries and domestic uses, both for lighting and power.

The function of the electrical system is to convey power from the point where it is produced to the many points where it may be required. It is a distributor, it performs many of the same functions in a power system as the pipes in a system for supplying water.

Back of any electrical system there must be a supply of power, and any method by which the cost of power may be reduced must therefore be regarded as being of the very highest and far-reaching importance. The steam engine is recognized as less efficient for developing mechanical energy from coal than the gas engine, but while the latter involves great possibilities, it has not been used to any appreciable extent. Mr. Westinghouse is quick to appreciate the future possibilities of experimental beginnings; he recognized the possibilities of the alternating current, and it was he who was foremost in upholding it during the years of opposition and controversy. Electrical engineering in America is doubtless many years in advance of what it would have been except for his foresight and energy. He is now exploiting the gas engine and is bringing it to a state of mechanical perfection in which its inherent possibilities may be realized and an advance made in the cheapening of power which will effect an industrial revolution.

A few years ago one would have scarcely imagined that there could be operations more diverse and having so little in common as the lighting of our streets and houses, the lighting of street cars, the driving of printing presses and elevators and fans, the heating of street cars and cooking utensils and the making of ice, and yet to-day all of them may be effected by the current from a single power station.

The combinations of capital which tend to the concentration of the power and electric interests of a city into a single system; the development of electrical apparatus to meet the requirements of such a system; the prospect for cheapening of power; the development of the various means by which power may be utilized, are all factors which indicate that it is the central station of the future, from which is to come the energy upon which industrial life and social activity and advancing civilization depend.

RECONSTRUCTED GRANITE AS AN INSULATING MATERIAL.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Thomas Wilkinson Blakey, of Keene, N. H., and Wm. Courtenay, of New York. Sub-Committee.—Geo. A. Hoadley, C. H. Bedell, Arthur J. Rowland, W. M. Stine.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2122.] PHILADELPHIA, November 7, 1900.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Reconstructed Granite Company's "reconstructed granite used as an insulating material for electrical purposes," reports as follows:

Reconstructed granite is a manufactured product, produced substantially as follows: Natural granite chips are calcined by being brought to a high temperature and afterward pulverized. It is then thoroughly mixed with pulverized feldspar and kaolin in definite proportions; enough water is added to make the mixture plastic, and it is then moulded into the desired forms under heavy pressure. After being dried it is subjected to a temperature of about 3,000° Fahrenheit, at which temperature it is fused into a homogeneous mass. When used for electrical purposes, the surface is given a vitrified glazing, which aids in increasing its insulating properties by rendering it less porous. The claims made for this material are as follows:

(1) It is absolutely fireproof.

(2) It resists the action of all solvents and acids except hydrofluoric, which attacks it superficially.

(3) It is frostproof.

(4) It is non-porous, and consequently does not absorb moisture.

(5) It has high crushing and tensile strength.

(6) It has high insulating qualities.

In investigating this material, your committee has made use of, first, experimental tests, and, second, the testimony of extensive users of the various forms of insulation blocks produced.

From the tests made, the reports on the various claims are as follows:

Claim 1.—A piece of broken insulator was heated until it became red hot, when it was plunged immediately into cold water. The only observed effect was a slight checking in the glazing in an angle of the specimen.

Claim 2.—Found to be substantially correct.

Claim 3.—No tests were made of its resistance to the action of frost.

Claim 4.—A piece of the material was weighed in November, 1899, and found to weigh 1706·2 grains. It was then placed in water and kept there until October, 1900, when it was found to weigh 1719·2 grains. It was then dried and lost all its moisture except ·2 grain, weighing 1706·4 grains. Computing the amount of absorption we found it to be ·76 per cent. of the weight of the specimen.

Claim 5.—Three tests for crushing strength and four for tensile strength were made by a member of the committee, with the following results:

CRUSHING.

	Pounds per Square Inch.
Specimen A	5,312
Specimen B	12,290
Specimen C	11,612

TENSILE STRENGTH.

	Pounds per Square Inch.
Specimen 1	1,005
Specimen 2	820
Specimen 3	973
Specimen 4	867

Claim 6.—The report of this test can best be given in a quotation from the report of the member making the test: "I tested the samples of 'reconstructed granite,' both with a megohm Weston voltmeter under 550 volts, and also with our D'Arsonval galvanometer and fifty silver chloride cells.

One volt deflection on the voltmeter is equivalent to 550 megohms, while the D'Arsonval instrument registers thousands of megohms. The samples are beyond the range of either instrument before soaking. After removing the glaze and soaking in salt water for two weeks, we can just get a very slight movement of the needle on our megohm voltmeter. We are safe in saying that the ohmic resistance of these samples is very high."

The testimony of the different users consulted by your committee does not cover all the claims, but is in part as follows:

"We have been using it (reconstructed granite) for third-rail insulators in large quantities, and have, therefore, subjected it to numerous tests in regard to the absorption of moisture, break-down qualities at different potentials, strength, etc., finding it to be extremely variable. In the case of absorption as much as 7 per cent. of its weight is often taken up, while in other instances it is as low as one-half of 1 per cent. * * * By thoroughly baking and drying out the material we have been able to get a resistance as high as 8 megohms, but upon subjecting it to steam for twenty-four hours, the resistance was as low as 20,000 ohms."

Another extensive user writes: "We use the reconstructed granite in connection with our railway equipments for several purposes. One is to support the panels in the resistance boxes, and to support the cast grid resistances to angle irons fastened under the car. For these purposes we find it a good insulator, and stronger than any vitrified brick that we are able to get hold of. We also use this granite in the controller as an arc deflector. * * * Breaking the heavy currents that are necessary on heavy elevated work, that is, 250 ampères, is quite a problem, and we found nothing else that would do as well for a deflector as this granite." "It is also used extensively, I believe, altogether by the elevated roads in Brooklyn as an insulator for the third rail."

The tests and testimonies herein cited have caused your committee to believe that an invention of decided commer-

cial importance has been made, and in consequence of this belief the Franklin Institute recommends that the John Scott Legacy Premium and Medal be awarded to Thomas Wilkinson Blakey, of Keene, N. H., and William Courtenay, of New York, N. Y., for their "Reconstructed Granite as a Material for Insulating Purposes."

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 5, 1900.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned,
H. R. HEYL,
Chairman of the Committee on Science and the Arts.

NOTES AND COMMENTS.

PROTECTING BUILDINGS FROM FIRE BY A WATER CURTAIN.

The *Iron Age* is authority for the statement that the method of protecting buildings from fire by the use of what is called a "water curtain," by which water can be caused to fall in a sheet all around the structure, is steadily growing in favor. The same journal conveys the information that the great building of the Public Library of Chicago is protected on this plan. The arrangement, which is extremely simple, is described as follows:

A 7-inch steel water main is laid around the top of the structure, upon the broad stone table formed by the top of the coping, this pipe having connection with force pumps situated in the basement, and, through perforations properly arranged, insures the introduction of a substantial sheet of water from cornice to pavement, around the whole or any imperiled portion of the building. The arrangement of the system of piping is such as to permit of operating in prescribed sections; additional relays of smaller pipe are also placed in position above windows and doors in order to complete the curtaining of those points in the most serviceable manner, should the curtain in the main be broken by wind impinging against the building. W.

HOW SHOULD BOILER-HEATING SURFACES BE CALCULATED.

In a paper lately presented to the American Society of Mechanical Engineers, Mr. C. W. Baker questions the correctness of the usual practice of computing the horse-power of steam boilers from the heating surface. He affirms that by the method usually followed, there results an error of from 7 to 17 per cent., which, he says, is due to the practice of taking the surface in contact with the water, instead of that in contact with the fire gases, as the heating surface. Where these surfaces are flat there will be no difference between

one side and the other, but the boiler-heating surface is made up largely of tubes, and in these there is a difference of 17 per cent. between the interior and exterior surface in the case of a 1-inch tube, and of 7 per cent. in the case of a 4-inch tube.

The error to which Mr. Baker calls attention lies in the failure to appreciate the fact that the heating surface of the boiler, on which its steaming capacity depends, is the actual surface exposed to the fire or fire gases. With clean metal, the actual difference of temperature between the two sides of a boiler plate (or tube) is never more than 1° Fahrenheit, and Lord Kelvin has observed that for all practical purposes, we may consider that the heating surfaces of boilers conduct heat as though they were no thicker than paper.

It follows from the foregoing observations that the temperature of the heating surfaces of steam boilers is that of the wet side, and not that of the fire side of the plate (or tube).

Although this fact is common knowledge among engineers, Mr. Baker claims that it has been generally overlooked by engineers and writers on engineering subjects, who have not insisted, as they should, that the fire side of boiler tubes should be that from which heating surfaces should be computed.

He illustrates his argument by the statement that if the fire side of the tubes be increased by forming ribs upon it—as is the case with the Serre tube—the steaming capacity of the boiler is thereby increased; but no such increase of steaming capacity will result from the placing of ribs on the wet side of the tubes.

Mr. Baker further makes the interesting statement that a thin coating of scale on the wet side of a boiler plate affects the steaming capacity less than a furring of soot on the fire side, which will be something of a surprise to most engineers. Another deduction of the author is that circulation of water in a steam boiler is of much less consequence than is generally supposed in its relation to efficiency. Good circulation is desirable because of its influence in assuring the equal heating of all parts of the structure, and hereby preventing undue strains in certain parts, but in Mr. Baker's judgment it can have no effect on economy or efficiency.

The points made by the author seem to be well founded, and should receive the serious attention of steam engineers. W.

PUBLICATIONS RECEIVED.

Geography in the Elementary Schools. By W. T. Harris, U. S. Commissioner of Education. From the author.

Rules and Suggestions as to Plumbing Work and Drainage, Sewerage and Sewage Disposal, Water Supply and Fire Protection. From the publishers, The Engineering News Publishing Company, New York.

Sanitary Engineering of Buildings. By Wm. Paul Gerhard, C.E. Advance sheets. From the publisher, Wm. T. Comstock, New York.

Shot Iron; how to recover it and how to use it. By C. H. Putnam, Moline, Ill. (Reprint from *Am. Foundrymen's Assoc.*) From the author.

The Open-Hearth Continuous Steel Process. By Benjamin Talbot (Pencoyd. Pa.). From Mr. James Christie. (Reprint from *Jour. Iron and Steel Inst.*, No. 1, 1900.)

U. S. Geological Survey. Mineral Resources of the United States. Calendar years 1890–1899. From David T. Day, Chief of Division of Mining and Mineral Statistics.

A Comparative Study of the Methods Used for the Measurement of the Turbidity of Water. By George C. Whipple and Daniel D. Jackson. (Reprint from *Technology Quarterly.*) From the authors.

A Study of Certain Shades and Globes for Electric Lights as Used in Interior Illumination. By Wm. Lincoln Smith, S.B. Part I. (Reprinted from *Technology Quarterly*, Sept., 1900.) From the author.

Une Langue Universelle, est elle possible? L. Lean, Dr. es. S. Paris: Gauthier-Villars, 1900. From the publisher.

Cochrane Heaters, for heating and purifying water for boiler-feed and other purposes. Harrison Safety Boiler Works, Philadelphia.

Letters on Brewing. Edited by Hantke's Brewers' School and Laboratories, Milwaukee, Wis.

Electrical Aërial Cableways. Telpherage. Circulars 8, 9, 10. From the Consolidated Telpherage Co., New York.

Machine Tools and Attachments. Imp. 4to, 724 pp. Embracing metal-working and wood-working tools and their attachments. (Illustrated.) From Manning, Maxwell & Moore, New York.

Les Matières Colorantes Azotiques. Par Georges F. Joubert. Small 8vo. (Encyclopédie scientifique des Aide Memoire.) From the publishers, Gauthier-Villars, Paris.

Report on the Census of Porto Rico, 1899. Lt. Col. J. P. Sanger, Director. Washington Govt. Print. 1900.

Annuaire pour l'An. 1901, publié par Le Bureau des Longitudes. Avec des notices scientifiques. Paris: Gauthier-Villars. 1901. (Price, 1.50 francs.)

The Secrets of the Sun and the Starry Universe. By Henry Raymond Rogers, M.D., Dunkirk, N. Y. Read before the Young Men's Literary Club of Dunkirk, June 12, 1900. (Illustrated, 8 vo, pp. 31.) From the author.

Report of the Commissioner of Education. 1898–1899. Vol. I, 8vo, pp. vii–1248. Washington: Government Print, 1900. From the Bureau of Education.

The Metric System. A paper read before the American Chemical Society, June, 1900. By Mr. Rufus P. Williams, President of the N. E. Association of Chemical Teachers. (8vo, pp. 8.) From the Decimal Association, London, England.

Encyclopédié Scientifique des Aide-Memoire. Travail des Metaux dérivés du fer. Par L. Gages, Capitaine d'artillerie. Small 8vo, pp. 202. (Price, 2.00 francs.) From the publishers, Gauthier-Villars et Massan, Paris.

BOOK NOTICES.

Theory and Calculation of Alternating Current Phenomena. By Charles Proteus Steinmetz, with the assistance of Ernst J. Berg. Third edition, revised and enlarged. 8vo, pp. 525–xx. New York: Electrical World and Engineer, Inc. 1900. (Price, $4.00.)

This work, of which the previous editions have been fully noticed in the *Journal*, is well known to the electrical engineering fraternity as a valuable compendium of alternating current phenomena and their calculation in connection with the design of alternating current machinery. In the present third edition, the treatment of the subject, more especially in relation to its application in engineering, is brought down to date. A number of new chapters have been added and many others have been more or less completely revised and enlarged. In its present form it will be welcomed by the electrical engineering world as a thoroughly modernized treatment of this important subject. W.

Mesures électriques. Leçons professées à l'Institut électrotechnique Montefiore, annexé à l'Université de Liège. Par Gérard (Éric), Directeur de l'Institut électrotechnique Montefiore, Professeur à l'Université de Liège. Grand in-8 de viii–532 pages, avec 217 figures. Cartonné, toile anglaise; 1901. Paris: Librairie Gauthier-Villars. (12 francs.)

The work herewith mentioned is an expansion of the author's *Leçons sur l'Électricité*, previously noticed in the *Journal*. It is devoted specially to the consideration of electrical measurements, the fundamental ideas on which these methods are based, and the methods of their application. W.

Laboratory Instructions in General Chemistry. Arranged by Ernest A. Congdon, Ph.B., F.C.S., Professor of Chemistry, Drexel Institute, Philadelphia (with 56 illustrations). Philadelphia: P. Blakiston's Son & Co. 8vo, pp. 110. (Price, $1.00.)

This work comprises a series of experimental studies to accompany a course in general chemistry. The scope of the work embraces the whole range of inorganic chemistry; and an appendix is attached covering a series of demonstrations in physical chemistry, to familiarize the student with laws and theories which form the basis of the science. The arrangement of the matter is substantially new and is very well done. The idea of interleaving the book to permit of the student incorporating therein notes of experimental work is also commendable. W.

Practical Lessons in Metal Turning. A handbook for young engineers and amateur mechanics. By Percival Marshall, Associate of the Inst. of Mechanical Engineers, etc. (With 193 original illustrations.) 12mo, pp. 166. London: Published for the proprietor of "The Model Engineer," by Dawbarn & Ward, Ltd.

This work is intended by the author as a practical guide for the amateur machinist and model-maker and appears to be well arranged for its intended purpose. W.

Victor von Richter's Text-Book of Inorganic Chemistry. Edited by Prof. H. Klinger, University of Koenigsburg. Authorized translation by Edgar F. Smith, Professor of Chemistry in the University of Pennsylvania (assisted by Walter T. Taggert, Instructor in Chemistry). Fifth American from the Tenth German Edition, carefully revised and corrected, with 68 illustrations on board and colored lithographic plate of spectra. (8vo, pp. 430-xv.) Philadelphia: P. Blakiston's Son & Co. 1900. (Price, $1.75.)

This fifth edition of a well-known text-book has been thoroughly modernized by the incorporation therein of the most recent well-established discoveries in the science, especially those relating to the general properties and the measurement of gases, the newly discovered constituents of the atmosphere, the modern theories of electrolysis, etc. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 20, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1901.

President JOHN BIRKINBINE in the chair.

Present, 140 members and visitors.

Additions to membership since last month, 29.

Mr. George Washington, of New York, presented a description of his system of incandescent oil lighting, illustrating the subject by the exhibition of a large series of lamps showing the development of the invention. These lamps employ heavy mineral oil, supplied to the burners by air pressure, and burned on the Bunsen principle in contact with a special mantle of the Welsbach type. The light produced by these lamps is very brilliant, and they are adapted especially for out-door use or for the lighting of large enclosed areas, where electric arc lighting is now commonly used. The lamps are claimed to yield as much as 500 candle-power with the consumption of ⅛ of a quart per hour. Discussed by Prof. A. J. Rowland. The subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. W. N. Jennings gave an account of his exploration of a newly-discovered cavern situated at Mapleton (near Huntingdon), Pa., and exhibited, with the aid of the lantern, a number of flash-light photographs of the interior, so far as it was possible to penetrate its recesses.

Mr. I. Newton Swope, of Mapleton, on whose property the cave was found, followed with an account of the manner in which the discovery was made. He stated that in making a blast in a limestone quarry which he is operating, an opening was accidentally disclosed, which, on being enlarged, gave access to what was subsequently found to be a cavern of evidently great but as yet unknown extent. A main passage has already been explored for a distance of 1,500 feet, and numerous lateral openings have been observed which evidently communicated with other extensive chambers, as a partial investigation disclosed. This conclusion also was strengthened by evidences

of the presence of a large flowing stream of water in immediate proximity to the explored portion.

There seems to be little doubt, from the preliminary and imperfect exploration of this cavern, that it will prove to be among the largest thus far found—excepting always the Mammoth Cave of Kentucky, which will probably always remain unique in this respect. It is of especial interest to notice in connection with the new discovery, that the various chambers and passages are richly decorated with stalagtitic and stalagmitic growths in great profusion, resembling in this respect the famous Cavern of Luray in Virginia. It is the intention of Mr. Swope to undertake at once a thorough exploration of the cavern, with the view of making it accessible.

The meeting passed a vote of thanks to Messrs. Jennings and Swope for giving the opportunity of hearing the first public announcement of this interesting occurrence.

The Secretary supplemented the remarks of the previous speakers by a few comments on the close similarity of the interior features of the Mapleton cavern with those of the celebrated Cavern of Luray, which, when he had the opportunity of visiting it, a few months after its discovery, was no more promising than this new one. He exhibited a few lantern views of Luray to afford the members the opportunity of comparing the two subterranean interiors. The similarity between them, in respect of the elaborate decoration of the walls and chambers, was quite noteworthy.

The Secretary called attention to an interesting exhibit of waste products derived from the operations of type founding, stereotyping, electrotyping, white metal working, etc., and a number of useful products obtained therefrom, which had been used to illustrate the presidential address of Mr. Joseph Richards before the Mining and Metallurgical Section; also a balance of Mr. Richards' design for automatically estimating the percentage of tin and antimony in such wastes.

An interesting historical relic, in the form of an old "fare register," was shown, which had been deposited in the Institute's collection by Mr. W. G. Deschamps, of Philadelphia. This apparatus was one of those used on the old omnibus line running in the early fifties, between the Stock Exchange and Frankford. The register is about 2 feet in diameter and weighing about 25 pounds, the face of the circular dial being elaborately ornamented by figures cast in brass, which are caused to go through the motions of striking a bell and an anvil when a fare is registered.

Adjourned. WM. H. WAHL, *Secretary*.

STANDING COMMITTEES FOR THE YEAR 1901.

The President has made the following appointments:

COMMITTEE ON LIBRARY.

BENJ. S. LYMAN,
F. L. GARRISON,
H. F. KELLER,
ARTHUR FALKENAU,
HENRY LEFFMANN,
EDWIN S. BALCH,
EDGAR MARBURG,
CHARLES J. REED,
LOUIS E. LEVY,
GEORGE F. STRADLING.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, March 6, 1901.*]

Mr. Louis E. Levy in the chair.

The following reports were adopted:

(No. 2107.) *Improvement in Grate Bars.*—James Reagan, Philadelphia.

Abstract.—This invention relates to grates of the rocking-bar type, its principal object being to keep the bed of fuel free from the clinkers and ashes that would ordinarily retard the admission of air to the combustion chamber. This is accomplished by a series of floating choppers which are borne by the rocking bars. For a description of the disposition of these choppers with reference to the rocking grate-bars and their mode of operation, the reader is referred to letters-patent of the United States Nos. 635,807–8, October 31, 1899.

By the use of this combination of devices, the inventor claims to be able to crush or dislodge all clinkers which are caught between the choppers and the

middle, end and intermediate bars of the grate frame, and to cut away and remove all ashes and masses of clinkers which form in the lower layers of the incandescent fuel. For general merit of the device, the Certificate of Merit is awarded to the inventor. [*Sub-Committee.*—John Hartman, J. M. Emanuel, Chas. A. Teal, Arthur M. Greene, Jr.]

(No. 2140.) *Pneumatic Clock.*—Augustus Hahl, Chicago.

This report is reserved for publication in full. An intelligible abstract is impossible without the aid of illustrations. The report of sub-committee is favorable, and recommends the grant of the John Scott Legacy Medal and Premium to the inventor. [*Sub-Committee.*—J. Logan Fitts, Geo. S. Cullen, H. R. Heyl, Lewis Breittinger.]

(No. 2160.) *Improved Threading Tool.*—Herman S. Dock, Philadelphia.

This report is reserved for publication in full. The report recommends the grant of the John Scott Legacy Premium and Medal to the inventor. [*Sub-Committee.*—Hugo Bilgram, H. F. Colvin, Lucien E. Picolet, A. Falkenau.]

(No. 2161.) *U. S. Standard Voting Machine.*—A. J. Gillespie, Rochester, N. Y.

(No. 2168.) *Bardwell Votometer.*—Arthur F. Bardwell, New York.

Neither of these reports is susceptible of abstract without the aid of illustrations. Reports in both cases are favorable. The award of the Edward Longstreth Medal of Merit is made. [*Sub-Committee.*—L. F. Rondinella, Geo. S. Cullen, Sam'l Sartain, Lewis M. Haupt.]

(No. 2169.) *Improved Sawing Machine and Guide.*—Frank A. Humphrey, Worcester, Mass.

ABSTRACT.—This invention is covered by letters-patent of the United States issued to applicant, Nos. 623,156 and 623,786, dated respectively, April 18 and April 25, 1899.

The invention relates to the class of sawing machines having a plurality of circular saws with swinging carriers and shifting devices adapted to bring the saws alternately to a common working position at the central opening of the work-supporting table that is adapted for tilting adjustment to both right and left inclination relatively to the plane of the saw when in working position.

The report, after dwelling upon the important features of the invention, concludes as follows: "A thorough examination of the state of the art * * * reveals the steps that have gradually led up to the * * * present invention. Its simplicity, compactness, ready adjustability to every class of work, thorough mechanical construction in both design and detail, and general convenience of operation, qualifies it to do most excellent work in large quantities."

The award of the John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—H. R. Heyl, T. H. Grigg, C. F. Albert.]

The following reports passed first reading:

(No. 2155.) *Improved Railway Tie.*—Philadelphia Railway Track Equipment Company, Philadelphia.

(No. 2158.) *Cash Register.*—The National Cash Register Company, New York.

(No. 2171.) *Water Sterilizer.*—The Forbes Company, Philadelphia.

The following cases were dismissed:

(No. 2190.) *Improved Mechanical Boiler Cleaner.*—Frank W. Hornish, Chicago, Ill.

(No. 2165.) *Steam Heater.*—The Prizer-Painter Stove and Heater Company, Reading, Pa.

A special committee consisting of Messrs. Fitts, Rondinella and Stradling was appointed to devise and submit to the General Committee a plan for a convenient method of indexing the committee's reports. W.

SECTIONS.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—The ninth stated meeting of Section was held Thursday, March 7th, at 8 o'clock. In the absence of the President, Dr. Leffmann was called to the chair. There were present 30 members and visitors.

Dr. I. N. Broomell read an interesting and instructive paper upon the "Use of Lantern Slides for Class Demonstrations." The speaker's remarks were profusely illustrated with an exceptionally fine series of slides, made by himself, and especially prepared for teaching dental anatomy, histology, etc. The thanks of the meeting were voted to Dr. Broomell.

Mr. John G. Baker exhibited a new and exceedingly ingenious and effective exposure meter of his own invention.

Dr. Leffmann made some useful suggestions as to the mounting and labelling of lantern slides, and exhibited some specimens embodying his ideas.

Mr. Frank V. Chambers, Editor of the *Camera*, Philadelphia, then introduced the subject of the Franklin Institute lending its patronage for the holding of a representative photographic exhibition, or salon, in Philadelphia, and after a general discussion of the subject, in which, among others, the following-named gentlemen took part: Messrs. Chambers, Leffmann, Sartain, Ives, Wager-Smith, Sawyer, the following motion was put and carried:

That the Executive Committee be instructed to consider the advisability of holding a general photographic exhibition in this city under the auspices of the Franklin Institute, and to report upon same at as early a date as possible, and that the Executive Committee be empowered to increase its numbers for this purpose. It was stated that the Art Club's galleries could be secured for such an exhibition.

F. M. SAWYER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, March 14, 1901. Mr. John F. Rowland, Jr., in the chair. Present, 34 members and visitors.

Mr. Cecil H. Taylor read a communication on "The Automatic Gun and its Military Aspects," which was referred for publication.

Mr. Henrik V. Loss presented a supplementary communication on "The Flow of Metal," answering some comments on his paper on this subject read and discussed at a previous meeting. Mr. Loss's communication was discussed by Mr. James Christie.

The subject was referred to the Committee on Publication. Adjourned.

DANIEL EPPELSHEIMER, JR.,
Secretary.

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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ANTARCTICA: A HISTORY OF ANTARCTIC DISCOVERY.*

BY EDWIN SWIFT BALCH.

(*Continued from p. 262.*)

Captain George Powell was at the Shetlands in November, 1821. D'Urville † says that Powell left Elephant Island on December 4, 1821, in company with Palmer, and that on the 6th they discovered the Orkneys, Powell sighting them first. On the 12th they named Washington Strait. D'Urville quotes Laurie as follows: "Les terres Trinity Land et

† "Voyage au Pôle Sud," Tome Deuxième, pages 13–16.

It is a singular fact that Powell appears to have received more recognition from the French than from his own countrymen. An account of his life may be found in the "Biographie Universelle, Supplément," Paris, L. G. Michaud, 1845. This gives the title of a paper, which I have not seen: "Chart of New South Shetland, with the Islands discovered in the sloop 'Dove,' George Powell, Master, Accompanied by a Memoir, 1822." [Laurie, London, November, 1822.]

Jules de Blosseville, Lieutenant de Vaisseau, wrote a long appreciative notice of Powell: "Mort du Capitaine Georges Powell;" *Revue des Deux Mondes*, III année, Tome I, Paris, 1831, pages 38–46. This Lieutenant de

Tower Island des premières cartes, par la position d'environ 63° ½ S. et 60° ½ sont abandonnées comme imaginaires, ou n'étant seulement que des montagnes de glace." D'Urville deduces from this that the name Palmer Land and not Trinity Land is the proper one for the north coast of the mainland. According to the track laid down on the English Admiralty charts, Powell approached Palmer Land only once, where he was nearly 1° north of Mount Hope, in about 62° 30′ south latitude and 57° west longitude.

Captain Weddell* made numerous sealing voyages in 1820–1823. He searched for the Aurora Islands, and concluded that they were really the Shag Rocks, in 53° 48′ south latitude, 43° 25′ east longitude. He visited the Shetlands several times and called one of them Smith's Island and another James' Island; from his chart, he appears always to have been on their north or eastern shore.

In February, 1823, Weddell, in the brig "Jane," and Mr. Matthew Brisbane, in the cutter "Beaufoy," made an important southern cruise. Standing south on the 4th of February, they were deceived by great ice islands into thinking they had sighted land. On the 14th, in 68° 28′ south latitude, 29° 43′ west longitude, the ice islands were so numerous as almost to prevent the ships passing. On the 16th, on the contrary, in 70° 26′ south latitude, 29° 58′ west longitude, "ice islands had almost disappeared, and the weather became very pleasant."† On the 18th the ships were in

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Blosseville must be the one lost in 1833 in the "Lilloise," on the East Greenland coast. See *Geographical Journal*, Vol. XVI, 1900, page 662.

Mr. P. Lee Phillips, Chief Map Division, Library of Congress, informs me that in Alexander G. Findlay's "A Directory for the Navigation of the Pacific Ocean," printed for R. H. Laurie, London, 1851, Part II, pages 658–660, there is an account of the Orkneys prepared from Powell's notes. Mr. Phillips also says that in *Journal des voyages découvertes et Navigations Modernes* (publié par Verneur et Frieville, 44 vols., Paris, 1818–30), 1824, Vol. 22, and in *Annales Maritimes*, 1824, Vol. I, there is an article entitled "Extrait des Voyages du Capitaine Powell à S. Shetland," 1821–1822. I have not been able to find these books.

* "A Voyage Towards the South Pole," performed in the years 1822–24. By James Weddell, Esq., Master in the Royal Navy. London: Longmans, Hurst, Rees, Orme, Brown and Green, 1825.

† "A Voyage," etc., page 34.

latitude 72° 38′ south. "In the evening we had many whales about the ship, and the sea was literally covered with birds of the blue peterel kind. *Not a particle of ice of any description was to be seen.* The evening was mild and serene."* On the 19th the ships were in latitude 73° 17′ south, longitude 35° 54′ west. On the 20th: "At 10 o'clock in the forenoon, when the ship's head was E. S. E., I took a set of azimuths, which gave variation 11° 20′ east. The atmosphere now became very clear, and nothing like land was to be seen. Three ice islands were in sight from the deck, and one other from the masthead. On one we perceived a great number of penguins roosted. Our latitude at this time, 20th February, 1822, was 74° 15′, and longitude 34° 16′ 45″; the wind blowing fresh at south, prevented, what I most desired, our making further progress in that direction. I would willingly have explored the S. W. quarter, but taking into consideration the lateness of the season, and that we had to pass homeward through 1,000 miles of sea strewed with ice islands, with long nights and probably attended with fogs, I could not determine otherwise than to take advantage of this favorable wind for returning.† * * * These considerations induce me to conclude, that from having but three ice islands in sight, in latitude 74°, the range of land, of which I have spoken, does not extend more southerly than the 73d degree. If this be true, and if there be no more land to the southward, the antarctic polar sea may be found less icy than is imagined, and a clear field of discovery, even to the South Pole, may therefore be anticipated."‡ Captain Weddell then sailed northward, on a course not far distant from his southerly one. His southern cruise is interesting, and what he says about warmer weather and little ice far south agrees with what Morrell reports of the same season. Weddell called his open sea "George IV Sea," but geographers are beginning now, with justice, to chart it as "Weddell Sea."

* "A Voyage," etc., page 36.
† "A Voyage," etc., page 37.
‡ "A Voyage," etc., page 43.

Morrell wrote a brief notice of Weddell, about whom he says:* "Captain James Weddell, of the British Navy, whom I have before mentioned in the previous chapter, as seeking for the Aurora Islands in 1822: a most excellent officer, and a highly worthy man: justly extolled as an active, correct and enterprising navigator. Being familiar with danger in its most appalling form, every emergency finds him cool, steady and undaunted. He is, in short, at once an honour to his country and to human nature. I speak with confidence, for I know him."

Captain Robert Johnson, in 1822, made a sealing cruise in the schooner "Henry," of New York. Captain Morrell writes about him:† "The schooner 'Henry,' Captain Johnson, who had been vainly cruising for six weeks in search of the Aurora Islands, returned to New Island on Wednesday, the 23d. (Note. The history of these *imaginary* islands will be found on a subsequent page.)" And later: "March 15th. * * * At this time the wind had hauled to the southwest, and at half-past four P.M. we were close in with the eastern coast of the land to which Captain Johnson had given the name of New South Greenland." ‡

Edmund Fanning also speaks of Captain Johnson:§ "This continent, it is asserted in Morrell's voyage, page 69, was named 'New South Greenland' by a Captain Johnson. It is but just to state here, that this most meritorious mariner (Captain Johnson) was a pupil to, and made his first voyage to the South Seas with, the author, with whom also he remained, rising to different stations, and finally became one of his best officers; the first information he obtained of the discovery of this land by Captains Pendleton and Palmer was from the author of this work."

Captain Johnson made another cruise in the year 1824 or 1826. "From this voyage he never returned. He was last seen at the South Cape of New Zealand, in the following year, having lost three men, who were drowned at Chatham

* "A Narrative of Four Voyages," etc., page 68.

† "A Narrative of Four Voyages," etc., page 53.

‡ "A Narrative of Four Voyages," etc., page 69.

§ "Voyages Round the World," etc., page 437.

Islands. * * * My informants further stated, that the 'Henry' left New Zealand on a cruise to the south and east, in search of new lands, between the sixtieth and sixty-fifth degrees of south latitude; and as he has never been heard of since leaving New Zealand, it is very probable that he made discovery of some new island near the parallel of 60 on which the 'Henry' was shipwrecked."*

Captain Benjamin Morrell, in the sealing schooner "Wasp," of Stonington, made a voyage to Antarctica in 1822–23.† He reached the Falklands on October 16th, then made a fruitless search for the Auroras, and afterwards steered for South Georgia. Thence he sailed for Bouvet Island, which he reached on December 6th and where he caught many seals. He gives its position as 54° 15′ south latitude, 6° 11′ east longitude. Sailing from there southward his ship was nipped on December 13th in 60° 11′ south latitude, 10° 23′ east longitude. After extricating himself, he sailed to Kerguelen Island, where he spent some time sealing. On January 11th he steered south and east, and in 62° 27′ south latitude, 94° east longitude, fell in with ice fields measuring at least 150 miles east and west. He continued east until February 1st, when he reached 64° 52′ south latitude, 118° 27′ east longitude. The wind now came fresh from the northeast, and Morrell turned west; "being, however, convinced that the farther we went south beyond 64° the less ice was to be apprehended, we steered a little to the southward until we *crossed the Antarctic Circle*, and were in latitude 69° 11′ S., long. 48° 15′ E. In this latitude there was *no field ice*, and very few ice islands in sight." He continued steering west until, on February 23d, he crossed the meridian of Greenwich in 69° 42′ south latitude. He now steered north and west for Sandwich Land.

After a short stay at Sandwich Land, Morrell left there

* "A Narrative of Four Voyages," etc., pages xxiii and 363.

† "A Narrative of Four Voyages to the South Sea, North and South Pacific Ocean, Chinese Sea, Ethiopic and Southern Atlantic Ocean, Indian and Antarctic Ocean," from the year 1822 to 1831. By Capt. Benjamin Morrell, Jun.; New York: J. & J. Harper, 1832, pages 59–69.

on March 8th, steering south and west. He was nearly caught by field ice, but broke through, and on March 14th reached 70° 14′ south latitude, 40° 3′ west longitude. Here the sea was free from field ice, and there were not more than a dozen ice islands in sight. The temperature of the air was 47° F., and of the water 44° F., both of which were higher than further north. Morrell also says that on the several occasions on which he crossed the antarctic circle he found the temperature both of the air and of the water became milder the farther he advanced beyond 65° south latitude.

From his most southerly point Morrell turned north-west, giving as his reasons for not penetrating further that he had no fuel and was short of water. On March 15th, in the afternoon, "we were close in with the eastern coast of the body of land to which Captain Johnson had given the name of New South Greenland." On March 16th the boats searched for seals on the coast, "the vessel following or keeping abreast of them, about two miles from the land, until the next day at 4 P.M. when we were in lat. 67° 52′ S., long. 48° 11′ W. * * * The coast here tended about S. E. by S., and we thought we could discern some of the mountains of snow, about seventy-five miles to the southward." Morrell then stood to the north.

Morrell has been severely assailed, for instance by D'Urville, Commander J. E. Davis, R.N.,* Dr. Fricker, etc. Some authors give as a reason for disbelieving in Morrell that his book is *rare*. At any rate there are two copies in the Philadelphia Library. It has also been said that his book "was withdrawn soon after Biscoe's discoveries were made known;" but as no authority is given for the statement, this needs confirmation. Captain (now Sir) R. V. Hamilton † wrote an able defence of Morrell, in which he said,

* In answer to Captain Hamilton. Commander Davis is the author of a paper: "On Antarctic Discovery and its Connection with the Transit of Venus in 1882;" *The Journal of the Royal Geographical Society*, Vol. XXXIX, 1869, pages 91–95.

† "On Morrell's Antarctic Voyage in the Year 1823," etc. *Proceedings of the Royal Geographical Society*, 1870, Vol. XIV, pages 145–156.

inter alia, "whatever else Mr. Morrell might not have discovered, he was the first discoverer of guano in the island of Ichaboe and Lobos. The speed of 120 miles a day, with which he made the voyage, was nothing uncommon as the sea was not encumbered with ice. * * * Mr. Morrell was a sealer, not an educated man, and therefore due allowance must be made for his errors." Dr. A. Petermann * appears to have believed in Morrell, for he says: "about the longitude there is probably a correction to be made of at least 5° to the west." Sir John Murray marks Morrell's positions on his map † apparently with Dr. Petermann's correction for longitude. Professor Angelo Heilprin ‡ likewise appears to consider Morrell trustworthy. Certainly some of Morrell's statements are hard to believe, and yet they are just possible. He may have reached 64° 52′ south latitude, 118° 27′ east longitude, and not seen the land. When he speaks of New South Greenland he refers almost surely to the western mainland. The two phrases, on March 15th and 16th, "we were close in with the eastern coast," and "the coast here tended about S. E. by S.," are noteworthy. For how did Morrell know that there was an eastern coast, if he had not been there? There may be an earlier mention of the eastern coast than that of Morrell, published in 1832, but if so, I have not come across it. This coast is not indicated on Weddell's chart nor on Vandermaelen's Atlas.§ Morrell's book is a bad and cheap piece of printing, and an error of a figure may easily have crept into the statement of longitude: 48° 11′ west, for 58° 11′ west. The proof of Morrell's statements about the Antarctic seems to lie in the sentence "and were in lat. 69° 11′ S., long. 48° 15′ E." If correct, then Enderby Land is an island

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* Petermann, A.: "Neue Karte der Süd Polar Regionen; *Mitteilungen aus Justus Perthes Geographischer Anstalt*," etc., von Dr. A. Petermann, 1863, pages 407–428. Page 415.

† Murray, John, Ph.D., LL.D.: "The Exploration of the Antarctic Regions;" *Scottish Geographical Magazine*, Vol. II, 1886, pages 527–548.

‡ Heilprin, Professor Angelo: "Our Present Knowledge of the Antarctic Regions;" *Popular Science Monthly*, New York, 1897, pages 323–336.

§ Vandermaelen, Ph.: "Atlas Universel de Géographie," Bruxelles, 1827.

or non-existent, and certainly the reports of the "Pagoda," the "Challenger," and the "Valdivia" show that further exploration in that quarter is necessary. Although Morrell's book is of little value as a scientific record, still it should be remembered in Morrell's favor that he was a sealer and not a scientist, that he had no instruments of precision, that the summer of 1823 was the most open in Antarctic records, and that even then Morrell does not claim to have reached as high a southern latitude as Weddell in the same year.

A Captain Hoseason (American?), according to D'Urville,* while seal hunting in 1824, may have discovered and given the names to Hughes Bay, Intercurrence, Three Hummock and Hoseason Islands, and Point Farewell. This seems to be rather in the nature of a guess on the part of D'Urville.

Captain Norris,† with the "Sprightly" and "Lively," belonging to Messrs. Enderby, on December 10, 1825, sighted an island in 54° 15′ south latitude, 5° east longitude. He called it Liverpool Island, but it is doubtless Bouvet Island. On the 13th he sighted another small island in 53° 56′ south latitude, 5° 30′ east longitude, which he called Thompson Island.

Captain Henry Foster, R.N., in 1828–1829, commanded an expedition to the South Shetlands ‡ for the purpose of making pendulum observations. After stopping at Staaten Land, where he met Captain Nathaniel B. Palmer, he sailed to the Shetlands and beyond to a place which he named

* "Voyage au Pôle Sud," Tome Deuxième, page 20.

† Ross, Sir J. C.: "Voyage," etc., Vol. II, pages 371, 372.

‡ "Narrative of a Voyage to the Southern Atlantic Ocean," in the years 1828–29–30, performed in H. M. sloop "Chanticleer," under the command of the late Captain Henry Foster, F.R.S., etc. From the private journal of W. H. B. Webster, surgeon of the sloop. London, Richard Bentley, 1834.

The Journal of the Royal Geographical Society of London for MDCCC-XXX–XXXI, London, MDCCCXXXI: VI.—"Account of the Island of Deception, one of the New Shetland Isles." Extracted from the private journal of Lieutenant Kendal, R.N., embarked on board his Majesty's sloop "Chanticleer," Captain Forster (*sic*), on a scientific voyage; and communicated by John Barrow, Esq., F.R.S. Read 24th January, 1831.

Possession Cape * in 63° 43′ south latitude, 61° 45′ west longitude, and on which he landed. Lieutenant Kendal thinks this was a new discovery, but he is clearly in error. The "Chanticleer" was then moored in the harbor (Yankee Harbor) of Deception Island on January 9, 1829, and remained there until March 4th, and during her stay numerous pendulum observations were made. The island is volcanic; some of the mountain peaks emitted smoke; and numerous hot springs bubbled up on the shores and the beaches.† Dr. Webster and Dr. Peter Conolan studied the fauna and flora of Deception Island.‡ They were much struck with the enormous abdominal vein of the leopard-seals.

Dr. Webster says of icebergs: "Having made some experiments of this nature,§ I deduced from them that in cubic pieces of ice one-seventh part only remained above the surface of the water. I also placed a cone of ice on a cubic piece from the same iceberg, and found that the cube easily floated and sustained the little pyramid, the height of which was more than double the depth of the cube below the water. I also floated irregular-shaped masses, and found their heights above the surface to vary considerably; in some it was equal, in others greater than the depth below it; proving that no inference can be safely drawn as to the depth to which an iceberg extends from the surface with reference to its height above it, and that all depends on its form. * * * In corroboration of this I may further observe, that while we were in contact with the iceberg off the island, we determined its height by a reference to the vessel's mast to be not less than fifty feet. Now this would have required a depth of three hundred and fifty feet to float in, according to the conclusion deduced from a cubical piece; but it was floating in ninety-six feet; for we obtained soundings at the same time with sixteen

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* D'Urville thinks this may be Hoseason Island.

† "Narrative of a Voyage," etc., Vol. I, pages 144–168; Vol. II, pages 273–280.

‡ "Narrative of a Voyage," etc., Vol. II, pages 300–306.

§ "Narrative of a Voyage," etc., Vol. I, pages 142–143.

fathoms of line." These observations of Dr. Webster deserve to be better known, for even to-day, apparently, it is often believed that the height of an iceberg above water is six or seven times less than its depth under water; and Dr. Webster, it would seem, was the first to note that this was not always the case.

Captain James Brown,* an American sealer, made a southern voyage in 1829–31 in the schooner "Pacific." He reported sighting four islands which were, at the time, not charted. The first, in 56° 18′ south latitude, 28° 35′ west longitude, he called Potter's Island. The second, in 55° 55′ south latitude, 27° 53′ west longitude, he named Prince's Island. The third, in 56° 25′ south latitude, 27° 43′ west longitude, he christened Willey's Island; and the fourth, in 57° 49′ south latitude, 27° 38′ west longitude, he called Christmas Island.

Mr. John Biscoe, in 1830–32, with the brig "Tula" and the cutter "Lively," Captain Avery, both ships belonging to the Messrs. Enderby, circumnavigated Antarctica,† sailing eastward. In November, 1830, he searched in vain for the Aurora Islands. On January 7, 1831, in 59° 35′ south latitude, 20° 21′ west longitude, Biscoe was stopped by smooth pack ice, which seemed to have been formed at sea; "nevertheless there were strong indications of land in the southwest." On the 21st, in 66° 16′ south latitude, 0° 24′ west longitude, there were many indications of land to the south and southeast. On February 1st Biscoe was in 68° 51′ south latitude, 12° 22′ east longitude; and on the 25th, in 66° 2′ south latitude, 43° 54′ east longitude, where he "saw a very distinct appearance of land." "At length, on the 27th, in latitude 65° 57′ south, longitude 47° 20′ east, land was distinctly seen, of considerable extent, but closely

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* "Fanning, Edmund: "Voyages Round the World," etc., pages 440–442.

† *The Journal of the Royal Geographical Society of London*, Volume the Third, 1833, pages 105–112; VIII.—"Recent Discoveries in the Antarctic Ocean." From the log-book of the brig "Tula," commanded by Mr. John Biscoe, R.N. Communicated by Messrs. Enderby. Read 11th February, 1833.

The Nautical Magazine for 1835, Vol. IV, Simpkin and Marshall, London; pages 265–275: "Voyage of the 'Tula' towards the South Pole."

bound with field ice." Efforts were made to close with the land, but owing to heavy gales the ships were driven off. On March 16th, however, "nearly the same land was again made; the longitude being now 49° E. A head-land, previously seen, was recognized, and called Cape Ann; and unceasing efforts were made, for some days, to approach nearer it, but all in vain." On April 6th Captain Biscoe finally turned north, "never having approached this forbidden land (which has, with great propriety, been called Enderby's Land) nearer than from twenty to thirty miles."

Biscoe sailed again south from New Zealand in January, 1832. He bore away southeast. On the 25th he was in 60° 45′ south latitude, 132° 7′ west longitude; on February 3d, in 65° 32′ south latitude, 114° 9′ west longitude; and on the 12th, in 66° 27′ south latitude, 81° 50′ west longitude; in all of which positions much ice was seen. On February 15th, in 67° 1′ south latitude, 71° 48′ west longitude, land was seen; this was called Adelaide Island; "and in the course of the ensuing fortnight, it was further made out to be the westernmost of a chain of islands, lying E. N. E. and W. S. W., and fronting a high continuous land, since called Graham's Land, which Captain Biscoe believes to be of great extent. The range of islands has been also since called Biscoe's Range, after the discoverer." "On the 21st of February Captain Biscoe succeeded in landing on what he calls the main land." The mountains here were named Mount Moberly and Mount William, the latter in 64° 45′ south latitude, 63° 51′ west longitude. Biscoe then repaired to the South Shetlands, and afterwards returned to England.

In 1833, an English sealer, named Kemp, is reported to have sighted land just east of Enderby Land, and it is marked "Kemp Land" on many atlases. Although Kemp's course is laid down on the English Admiralty charts, there is, apparently, no published account of his journey.*

* The sum total of added knowledge in these sixty years, judging from Hugh Murray's "The Encyclopædia of Geography" (Philadelphia, Carey, Lea & Blanchard, 1837, Vol. III, pages 172-173), had led to a general belief, in 1837, that round the South Pole was an archipelago of islands, and not a continental mass. Murray refers to the Antarctic under the title "South

Mr. John Balleny, an English sealer, sailed from Chalky Bay, New Zealand, on January 7, 1839, with the schooner "Eliza Scott," and the cutter "Sabrina." * He worked his way south, westward of 170° east longitude, and on February 1st was in 69° south latitude, 172° 11′ east longitude, where the pack was so thick that he turned north. On February 9th he discovered three islands in 66° 22′ south latitude, 163° 49′ east longitude, landed on one of them on February 12th, and found that it was volcanic in origin.

From these islands, since appropriately called the Balleny Islands, Balleny worked up northward and then westward. He met with a good deal of ice. His log says:

"*March 1st.*—With a steady breeze from the S. E. continued standing to the westward—passed several icebergs, and numerous flocks of penguins, petrels, and mutton birds.

"*March 2nd, A. M.*—Squally from the S. E., with snow and sleet. At 8 cleared off a little. At noon, lat. obs. 64° 58′, long. 121° 8′, therm. 35°. P. M., strong winds, and showers of snow and sleet; saw a great many birds. At 8, the water becoming smooth all at once, shortened sail, and hove-to. Saw land to the southward, the vessel surrounded by drift ice. At midnight strong breezes with snow.

Polar Islands," and begins: "The islands of the Southern Polar Sea, to which Monsieur Balbi gives the somewhat too pompous title of Antarctic Archipelago, extend chiefly," etc. He says also: "In 1831, Captain Biscoe fell in with land, in 66° S. lat. and 47° E. long., to which he gave the name of Enderby Land, and which he conceives to be of considerable extent. In the following year, he touched upon another coast of uncertain extent, in about the same latitude, and in long. 70° W. To this latter tract has been given the name of Graham Land." This paragraph of Murray is interesting, for it proves that the discovery of Enderby Land did not, at the time, give to geographers any idea of a South Polar Continent, but only that another island had been found. My attention was called to Murray's work by Mr. Edward E. Hale's "Stories of Discovery," Boston, Roberts Brothers, 1887.

* *The Journal of the Royal Geographical Society of London*, Volume the Ninth, 1839, pages 517–528; VI: "Discoveries in the Antarctic Ocean, in February, 1839." Extracted from the journal of the schooner "Eliza Scott," commanded by Mr. John Balleny. Communicated by Charles Enderby, Esq.

A brief note about the claims of Balleny as a discoverer is found in *Proceedings of the Royal Geographical Society of London*, Vol. II, 1858, pages 171, 172: "Note on Sabrina Land," etc., by Charles Enderby.

"*March 3rd, A. M.*—Found the ice closing and becoming more compact; stood through the drift ice to the southward. At 8 h. found ourselves surrounded by icebergs of immense size; to the S. W. the ice was quite fast, with every appearance of land at the back of it, but the weather coming on thick, were obliged to steer to the northward along the edge of the pack. At noon, lat. by obs. 65° 10′, long. 117° 4′. P. M., Fresh breezes from the S. S. E. and clear; numerous icebergs in sight."

The two sentences "saw land to the southward" and "the ice was quite fast, with every appearance of land at the back of it," are the only references to the great mass of land south of Australia.* Balleny never suggested nor evidently even suspected that he was on the edge of a continent, or that he had sighted anything but another island. That no one in England, at the time, thought the matter of any importance is shown by the fact that the editor of *The Journal of the Royal Geographical Society* placed as running heading at the top of page 525: "Sturge Island—Brown's Peak—Borradaille Island." Three of the Balleny Isles! There is nothing about Sabrina Land! This does not, however, alter the fact, and there appears to be no doubt that Balleny had a glimpse of the eastern mainland of Antarctica.

Balleny continued on his westerly course. On March 13th he wrote: "Light variable winds from the eastward; surrounded by icebergs: in lat. 61°, long. 103° 40′, passed within a ¼ of a mile of an iceberg about 300 feet high, with a block of rock attached to it."† About this his editor commented as follows: "We will, therefore, only add that this iceberg was distant 1,400 miles from the nearest *certainly-*

* Sir James Ross says ("Voyage," etc., Vol. I, page 272) that the log of Balleny states that on February 26th they thought they saw land in 64° 40′ south latitude, 131° 35′ east longitude, but that they concluded it was fog.

† As a sort of appendix to this paper is: "VI. Note on a Rock Seen on an Iceberg in 61° South Latitude;" *The Journal of the Royal Geographical Society of London*, Vol. the Ninth, 1839, pages 528-529, by Charles Darwin. He thinks such transported boulders are rare in Antarctica, but that, nevertheless, "the bottom of the Antarctic Sea, and the shores of its islands, must already be scattered with masses of foreign rock,—the counterpart of the erratic boulders" of the northern hemisphere."

known land, namely Enderby's Land, which bore W. S. W. of it. But it is highly probable from the compact nature of the ice, etc., that land extends between the parallels of 66° and 68° S., in which case the iceberg would not be distant above 300 miles from this supposed land. The appearance of land seen by Captain Balleny on the 3d of March, as above mentioned, bore from the iceberg E. S. E., distant 450 miles." Balleny then returned to England, apparently without making any stops, so that his discovery could not have been known to either Wilkes or D'Urville when they sailed.

Captain Dumont D'Urville,* in January, 1838, with the "Astrolabe," and Captain Jacquinot, with the Zélée," sailed southward from the Strait of "Magalhaens." On January 15th they found the first icebergs, in about 59° 30′ south latitude. On January 22d, in about 64° south latitude, due south of the Orkneys, they were stopped by an icy barrier extending along the entire horizon. The *corvettes* followed the line of the pack for more than 200 kilometers, coming back to 61° south latitude, north of the Orkney Islands. D'Urville wished to follow the tracks of Weddell, and, therefore, turned once more southeast, when he again met an icy barrier between 62° and 63° south latitude. In trying to break through the pack, the vessels were nipped, and for five days were in a good deal of danger. Finally, a strong southerly gale opened the pack somewhat, and with the help of saws and axes, they succeeded in breaking loose. On February 15th D'Urville returned westward, examined again the Orkneys and some of the Shetlands, and then succeeded in getting a little further south, where between 63° and 64° south latitude he sailed over 100 kilometers along the coast of Palmer Land, which he renamed Louis Philippe Land and Joinville Land, although it had been previously visited by Palmer and Johnson. Scurvy having appeared on his ships, he then returned north.

* "Voyage au Pôle Sud et dans l'Océanie, sur les Corvettes 'l'Astrolabe' et 'la Zélée,'" sous le commandement de M. J. Dumont-D'Urville, capitaine de vaisseau. Publié par ordonnance de Sa Majesté, sous la direction supérieure de M. Jacquinot, capitaine de vaisseau: Paris, Gide et Cie, éditeurs, 1845; Tome Deuxième.

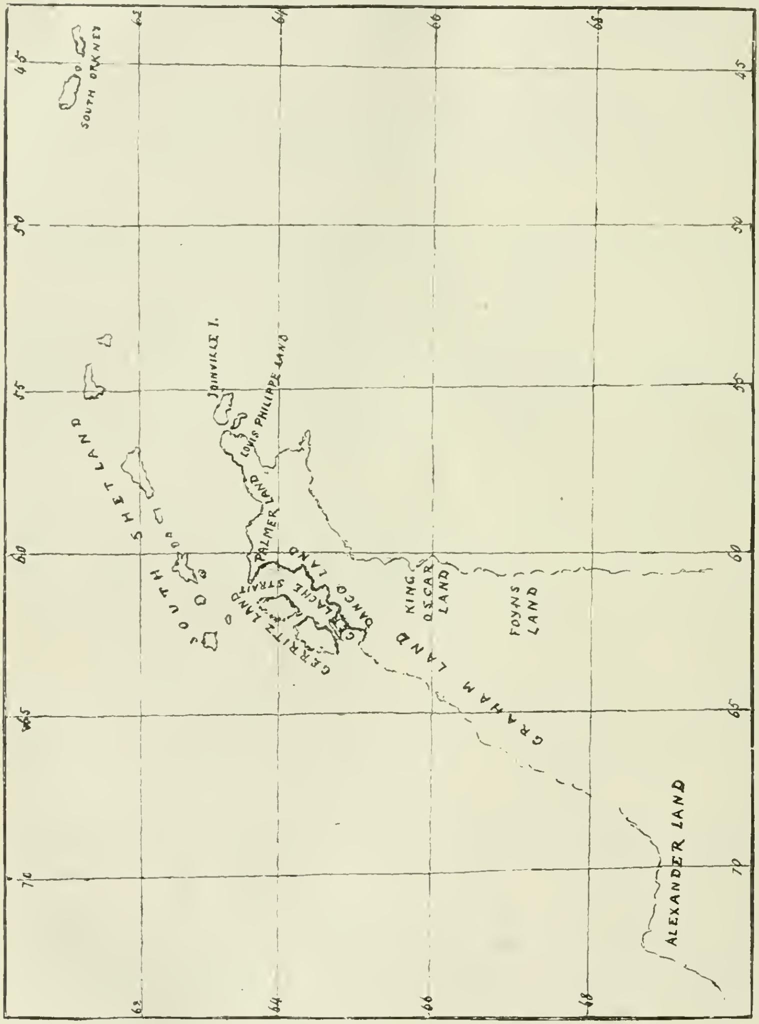
D'Urville mixed up the nomenclature of the western mainland of Antarctica. Before his visit, the northern coast was known to the Americans as Palmer Land, to the English as Trinity Land. I have found no record stating who gave the name Trinity Land, but it appears to have been used first by Powell. Vandermaelen's "Atlas" in 1827 outlines the northern coast under the name "Trinité." D'Urville simply wrote Trinity Land on Palmer Land, and moved Palmer Land into Gerlache Strait and on to Gerritz Archipelago, so as to get room for his own names. As Palmer was the first on this coast, his name ought certainly to be restored to at least its western portion, from Gerlache Strait to Mount Hope. As D'Urville, however, made the first fairly detailed chart of the eastern portion of this coast, he has claims to recognition, and the name Louis Philippe Land might be kept from Mount Hope to Joinville Island. It seems as if this would be perhaps the fairest rearrangement of names, and I have drawn a rough chart giving this nomenclature.

Two years later D'Urville made another cruise south.* He started from Hobart Town on January 1, 1840. On January 16th the watch signalled the first ice; on the 18th, they had reached 64° south latitude; on the morning of the 19th, six enormous ice islands were floating round them; finally, about 3 o'clock on the afternoon of the 19th, Monsieur Gervaize, who was on watch, noticed "a grey spot, which appeared stationary;† but already we had so often been led into error by these false appearances, so frequent in these regions, that we had become very suspicious. Monsieur Dumoulin, who was on deck, occupied at that instant in charting the various ice-islands which were in sight, hastened to ascend the rigging so as to clear up all doubts; he assured himself that the indications noted by Monsieur Gervaize had reference to a cloud, which, seen from the height of one of the spars (*hune d'artimon*), appeared to be above the horizon. On descending, he announced to

* "Voyage au Pôle Sud," etc., Tome Huitième, pages 123–185.

† "Voyage au Pôle Sud," etc., Tome Huitième, page 136.

me besides, that straight in front of us, there was an appearance of land much more distinct and more noticeable; it was, in fact, Adélie Land. Thanks to this circumstance,



Sketch chart of lands south of South America.

Monsieur Dumoulin was the first one of us all who saw the land."

On the 20th, owing to lack of wind, they could not get any nearer to the coast, and there remained, on the "Astro-

labe," more than one doubter as to its existence. But at midday all uncertainty ceased, as a boat sent from the "Zélée" announced that since the day before they also had seen land. On the 21st a light wind enabled the ships to close in with the shore. As they progressed, ice islands became more numerous, and by eight o'clock the *corvettes* were so hemmed in by these enormous masses of ice that D'Urville feared every instant seeing his ships wrecked. During the day, however, they worked their way through until they were in a small (Piner's) bay:

"The land which was in sight now showed us the few accidents it presented:* it stretched as far as the eye could see to the southeast and to the northwest, and in these two directions we could not see its limits. At no place did it show any rising summit. At no place either could one see any spot indicating the soil, and one might have thought that we had arrived before an ice-barrier still bigger than all those we had already met, if we could have been able to admit that ice-barriers ever could reach such a prodigious height. Its shore showed everywhere a vertical cliff of ice, similar to those we had observed in the floating islands we had been sailing past. This aspect of the coast was so exactly alike to the one which these floating bergs had shown us, that we did not retain the least doubt as to the formation of these latter. Moreover, on several points of the shore, we could see besides a good number of floating islands, which seemed barely separated from the land where they had formed and to be awaiting only the influence of the winds and of the currents to go out to sea. The elevated parts of the land showed everywhere an uniform tint; they ended at the sea by a gently inclined slope; thanks to this arrangement we could see a pretty considerable stretch of country. At several points, we noticed that the snows which covered the soil showed a broken and irregular surface. One could perceive regular waves, like those which the winds dig in sand deserts. It was especially in the least protected portions that these acci-

* "Voyage au Pôle Sud," etc., Tome Huitième, pages 143–145.

dents appeared strongest. At other spots, this crust of ice seemed also traversed by ravines or cut out by the waters. The sun shone in all its splendor and added greatly to the already so imposing aspect of this mass of ice. With our glasses we examined at every instant this mysterious land, whose existence it seemed could no longer be contested, but which had not offered to us as yet any absolutely certain proof of its existence."

Suddenly, however, some black spots were seen by Monsieur Duroch in the bay, and these turned out to be several small islands. Boats were sent from both *corvettes*, and some members of the expedition landed on one of the islands, on which they ran up the *tricolore* flag, and of which they took possession, as well as of the adjoining coast, in the name of France. The ceremony was concluded by drinking a bottle of Bordeaux wine. The little island was a bare rock, and did not offer the slightest trace of lichens. The animal kingdom was represented only by penguins, and not a single shell was found. "Up till then and during the whole time when there might have been doubts, I had not been willing to give a name to this discovery, but on the return of our boats I christened it Adélie Land. The most prominent cape which we had seen during the morning, at the time we were trying to get nearer to the land, received the name of *Cap de la Découverte*. The point near which the boats landed, and where they were able to collect geological specimens, was called *Pointe Géologie*."*

A tremendous storm arose shortly afterwards, and the ships were in danger, but succeeded in reaching open water. After the storm had ceased, they returned again south, but further west, and on the 29th, nearly off Cape Carr, met the U. S. S. "Porpoise," Commander Ringgold, but owing to a misunderstanding, they did not communicate. On the 30th the French ships sailed for a distance of 20 or 25 leagues, along a wall of ice which was from 30 to 45 meters high. This ice bluff was too elevated to permit the explorers to distinguish the details of the interior. "Thus, for more

* "Voyage au Pôle Sud," etc., Tome Huitième, page 154.

than twelve hours, we had followed this wall of ice which was perfectly vertical on its sides and horizontal on its top. Not an irregularity, not the slightest prominence broke this uniformity during the twenty leagues which were sailed over during the day. As for the nature of this enormous wall, as about the appearance of Adélie Land, opinions were again various; some held that it was a compact mass of ice independent of any land, others, and I share this opinion, contended that this formidable belt was at least an envelope, a crust, to a solid base, either of earth or rocks, or even of high placed shallows spread out around a great land. In this, I always base myself on the principle that no ice of great size can form in the open sea, and that it always needs a solid supporting position to enable it to be fixed in a definite spot. However this may be, at ten o'clock in the evening I started to the southwest, after having christened the ice barrier we had just examined, *Côte Clarie*."* D'Urville stood north from here, and on February 17th reached once more Hobart Town.

D'Urville's cruise is important. His narrative is so lucid that it is unnecessary to comment at length on it. It may be well, however, to call attention to the fact that both Wilkes and D'Urville saw this part of Wilkes Land, and that the narratives and the charts of the two explorers tally in all respects. Wilkes, however, saw even more than did D'Urville, for Wilkes, as his chart shows, went close to the coast between Piner's Bay and Cape Carr.

In 1839 Lieutenant Charles Wilkes, U.S.N.,† commanding the United States Exploring Expedition on a voyage around the world, sailed on February 25th from Orange Harbor, Tierra del Fuego.‡ He was on the gun-brig "Porpoise," with the pilot boat "Sea-Gull," 110 tons, commanded by Lieutenant Johnson, as tender. On March 1st they sighted Ridley Island in the South Shetlands. On the 2d

* "Voyage au Pôle Sud," etc., Tome Huitième, pages 175-177.

* "Narrative of the United States Exploring Expedition," during the years 1838, 1839, 1840, 1841, 1842, by Charles Wilkes, U.S.N., Commander of the Expedition. Philadelphia, Lea & Blanchard, 1845.

* "Narrative U. S. E. E.," Vol. I, pages 133-145.

they made O'Brien, Aspland and Bridgeman Islands. On the 3d they sighted Mount Hope, the eastern extremity of Palmer Land, in 63° 25′ south latitude, 57° 55′ west longitude. They also discovered three small islets, which Wilkes christened the Adventure Islets. There were many icebergs floating about and too much ice along the coast to attempt landing. The "Sea-Gull" returned north on March 5th. On the 7th the "Porpoise" was nearly wrecked on some high land, which proved to be Elephant Island. This is of volcanic appearance and its valleys were filled with ice and snow.

On February 25th, also, two other ships of the United States Exploring Expedition sailed from Orange Harbor.* These were the "Peacock," Captain Hudson, and the "Flying Fish," Lieutenant William M. Walker. On March 11th they saw the first iceberg. On the 13th their position was in 64° 27′ south latitude, 84° west longitude. On the 14th Captain Hudson remarked a great and striking change in the weather, as since 62° south latitude it had become much more settled and free from the sudden squalls and constant gales they had experienced after leaving Cape Horn. On the 17th and 18th, however, they had another heavy gale. On the 20th the "Flying Fish" was in 67° 30′ south latitude, 105° west longitude. A cast of the lead showed no bottom in 100 fathoms. The water was much discolored, and Lieutenant Walker afterwards observed this same discoloration of the water in the vicinity of extensive masses of ice; he thought it might possibly be produced by refraction. The "Flying Fish" at this time was in a fog. This lifted and disclosed a wall of ice from 4 to 6 meters high, extending east and west as far as the eye could reach, and spreading out into a vast and seemingly boundless field to the south. Some floating ice had the appearance of being but lately detached from the land. On the 20th the "Peacock" was in 68° south latitude, 90° west longitude, and obtained a sight of an icy barrier of field-ice and icebergs. On the 21st the "Flying Fish" was in 68° 41′ south latitude,

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* "Narrative U. S. E. E.," Vol. I, pages 149–161; 405–408; 408–414.

103° 34′ west longitude, running among ice-islands. On the 23d the "Flying Fish" reached 70° south latitude, 100° 16′ west longitude; here they observed an appearance of land,* and saw large masses of ice and numerous icebergs. They then turned northward, and fell in with the "Peacock" on the 25th, in 68° south latitude, 97° 58′ west longitude. The two ships then returned together to Orange Harbor.

[*To be continued.*]

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.†

By George W. Colles, A.B., M.E.

(*Continued from p. 282.*)

Pressure Relations.—Considering now the question of terminal pressure as affected by phase relations, this matter has been very fully dealt with mathematically by several electricians, among whom we may mention Professor Ayrton[46] and R. M. Friese.[47] Assuming for simplicity a theoretical sine-distribution over the armature for the magnetic flux—a condition which, however, does not occur in practice—the mode of determining the pressure between any two slip-rings is as follows: Let the sinusoidal curve shown in *Fig. 1* (Plate XVIII) represent the curve of magnetic flux, the abscissas being angular distances on the periphery of the armature and the ordinates the flux density at each point. If the total flux be represented by N and its maximum density by N_m, then the equation of the curve is

$$\Phi = N_m \sin \vartheta,$$

ϑ being any angular distance from the neutral point; and the value of the total flux is

$$N = N_m \int_0^\pi \sin \vartheta \, d \vartheta = 2 N_m$$

* The existence of land at this spot was disproved by de Gerlache. See *post.*

† A thesis presented in candidature for the degree of Master of Science, in the Columbian University, May, 1900.

[46] *Jour. I. E. E.*, V. 22, p. 340, April 27, 1893.

[47] *Elektrotech. Zeitsch.*, Feb. 15, 1894.

The electromotive force induced at any point of the armature is proportional to the flux at that point, and is equal to

$$k\, N_m \sin \vartheta,$$

where k is a constant depending on the speed of rotation and the number of conductors per unit length of periphery; and the E.M.F. for any angular breadth

$$\frac{2\,\pi}{s}$$

of the armature periphery, where s is the number of phases or armature segments, is

$$k\, N_s = k\, N_m \int_{a}^{a + \frac{2\,\pi}{s}} \sin \vartheta \, d\, \vartheta$$

$$= k\, N_m \left[\cos a - \cos\left(a + \frac{2\,\pi}{s}\right)\right],$$

a being the angular distance of the rear end of the segment from the neutral point. Reducing this expression further to the simple sinusoidal form, we obtain

$$k\, N_s = k\, N_m \left[\left(1 - \cos \frac{2\,\pi}{s}\right) \cos a + \sin \frac{2\,\pi}{s} \sin a\right]$$

$$= \sqrt{2 - 2 \cos \frac{2\,\pi}{s}}\; k\, N_m \cos\left(a - \tan^{-1} \frac{\sin \frac{2\,\pi}{s}}{1 - \cos \frac{2\,\pi}{s}}\right)$$

$$= k\, N \sin \frac{\pi}{s} \cos (a - \beta),$$

where

$$\tan \beta = \frac{\sin \frac{2\,\pi}{s}}{\operatorname{vers} \frac{2\,\pi}{s}} = \frac{2 \sin \frac{\pi}{s} \cos \frac{\pi}{s}}{2 \sin^2 \frac{\pi}{s}} = \cot \frac{\pi}{s}$$

We see from this and from *Fig. 2* that this angle β is the complement of $\frac{1}{2}$ the phase-angle, or

$$\frac{\pi}{2} - \frac{\pi}{s};$$

hence

$$k\,N_s = k\,N \sin\frac{\pi}{s}\cos\left(a - \frac{\pi}{2} + \frac{\pi}{s}\right)$$

$$= k\,N \sin\frac{\pi}{s}\sin\left(a + \frac{\pi}{s}\right).$$

This shows that the maxima and minima are where the segment is bisected by the point of maximum flux density and the neutral line, respectively.

The maximum E.M.F. is

$$k\,N \sin\frac{\pi}{s},$$

and the virtual is accordingly, on well-known principles,

$$\frac{k\,N}{\sqrt{2}}\sin\frac{\pi}{s};$$

and as the direct-current E.M.F. is, by the common formula, $k\,N$, the ratios of the maximum and virtual alternating E.M.F. to the latter are thus simply

$$\sin\frac{\pi}{s} \text{ and } \frac{1}{\sqrt{2}}\sin\frac{\pi}{s},$$

respectively.

We obtain thus the following pressure ratios for different values of s:

Number of segments or slip rings $= s$.	Ratio of $A\,C$ to $D\,C$ pressure.	
	Maximum $= \sin\frac{\pi}{s}$	Virtual $= \frac{1}{\sqrt{2}}\sin\frac{\pi}{s}$
2 (monophase)	1	$\frac{1}{\sqrt{2}} = \cdot 7071$
3	$\frac{\sqrt{3}}{2} = \cdot 866$	$\frac{\sqrt{3}}{2\sqrt{2}} = \cdot 6123$
4	$\frac{\sqrt{2}}{2} = \cdot 707$	$\frac{1}{2} = \cdot 5$
6	$\frac{1}{2} = \cdot 5$	$\frac{\sqrt{2}}{4} = \cdot 3535$
8	$\frac{\sqrt{2 - \sqrt{2}}}{2} = \cdot 383$	$\frac{1}{2}\sqrt{1 - \frac{\sqrt{2}}{2}} = \cdot 2706$

For opposite armature connections we have, of course, in all cases the same pressure ratio as in the first of the above instances.

We may also show these pressure relations graphically to the eye, as in *Fig. 3*, which we may suppose to represent the armature in outline. The arcs A 2, A 3, A 4, etc., are the phase-angles

$$\frac{2\pi}{s}$$

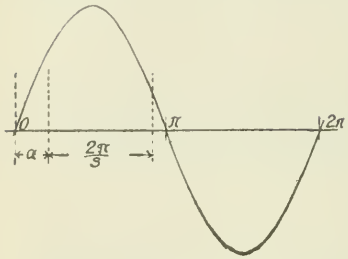

Fig. 1.

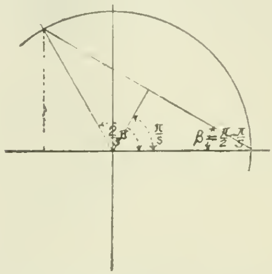

Fig. 2.

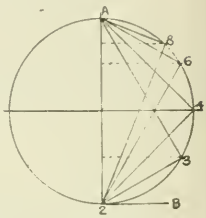

Fig. 3.

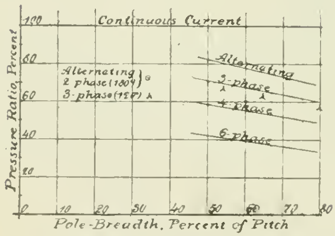

Fig. 5.

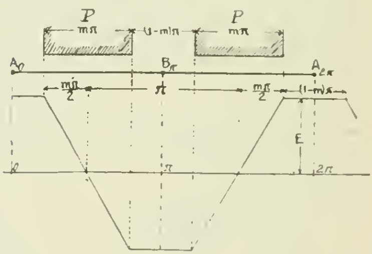

Fig. 4.

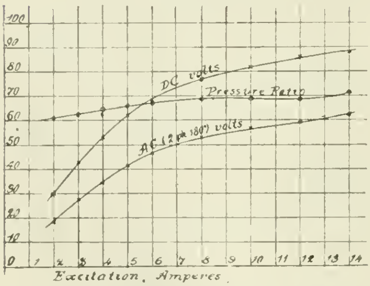

Fig. 6.

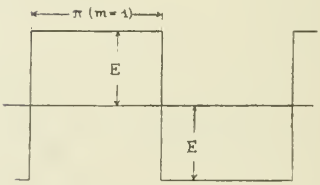

Fig. 7.

PLATE XVIII.—Pressure relations in the single-coil transformer.

for the different connections; the angles A 2B, A 23, A 24, etc., are then equal to one-half the phase-angles or to

$$\frac{\pi}{s},$$

and the chords *A* 2, *A* 3, etc., are in the ratio of the sines of those angles. Hence we see that the maximum pressure obtained for any given angular span of the armature is proportional to the chord of that angle. This is also evident from the consideration that the amount of magnetic flux cut by any segment is proportional to its projection on the neutral line, owing to the assumed even distribution of the flux across that line.

This is the voltage relation on theoretical assumptions; but these are not realized in practice. Routin[48] and Kapp[49] have worked out the voltages on the assumption of equal distribution of the magnetic flux over the surface of the pole-pieces, and assuming different breadths of pole-face. This assumption gives us an irregular flat-topped curve of electromotive force formed of broken straight lines, whose minor characteristics vary according as the breadth of pole-face is greater or less than 90 electrical degrees, and according to the width of armature segment, and whose maximum ordinate is of course equal to the direct current E.M.F., but the square root of the mean square of an ordinate, which measures the virtual alternating volts, varies with the shape of the curve, increasing as the pole-piece is narrowed, and the flat portion of the curve, hence also its area, becomes greater. This case is worked out for a 180° phase-angle (alternating current) in *Fig. 4*, where *P P* represent the pole-pieces, supposed to be of a breadth m, and the line *A B A* immediately beneath, the armature developed. The abscissas of the curve are taken opposite the position of the point *A*; the slip-rings being supposed connected at *A B*. Let E be the direct current pressure and e_v the virtual alternating pressure; then we have

$$\pi e_v^2 = \frac{8 E^2}{m^2 \pi^2} \int_0^{\frac{m \pi}{2}} x^2 \, d x + E^2 \int_{\frac{m \pi}{2}}^{\pi - \frac{m \pi}{2}} d x$$

$$= \frac{m \pi E^2}{3} + \pi E^2 (1 - m)$$

[48] *L'Eclairage Elec.*, V. 11, p. 531, June 12, 1897.

[49] *Elektrotech. Zeitsch.*, V. 19, p. 621, Sept. 15, 1898.

whence

$$e_v = E\sqrt{1 - \frac{2m}{3}}$$

whence we see that

For $m = \frac{3}{4}$, $\quad e_v = \frac{E}{\sqrt{2}} = \cdot 707\, E$

For $m = \frac{2}{3}$, $\quad e_v = \frac{\sqrt{5}}{3} E = \cdot 745\, E$

For $m = \frac{1}{2}$, $\quad e_v = \sqrt{\frac{2}{3}}\, E = \cdot 816\, E$

From this we see that when the pole-piece has a breadth equal to three-fourths of the pitch, the pressure ratio will be the same as with the sinusoidal distribution, and for breadths less than this, the alternating pressure, that is to say, the *ratio of conversion*, is raised; and by diminishing the former to one-half the pitch, we may raise the latter by as much as 15 per cent.

In a similar manner Kapp deduces the following values:

Voltage for	Sine Law.	Pole-breadth ⅔.	Pole-breadth ½.
Continuous Current	100	100	100
Alternating Current	70·7	75	82
Three-phase	61·2	65	71
Four-phase	50	53	58
Six-phase	35·4	37	42

The assumption of uniform flux-distribution over the pole-faces is doubtless nearer to actual practice than the sine-law; still it does not appear to exactly represent the actual distribution, which is in general something between the two assumptions, slightly intensified at the center and fringing out at the edges. Thus, a 55-kilowatt three-phaser described by Thompson,[50] whose pole-breadth was 54 per cent. of the pitch, had a ratio of conversion of only 66·6 per cent., which shows less average concentration of the field than is required by the above table. The same machine had had originally a pole-breadth of 80 per cent., which gave a conversion ratio 57·7 per cent. In another case, a 600-kilowatt four-phase machine, the pole-breadth was 72 per cent., and

[50] *Jour. Inst. E. E.*, V. 27, p. 680, Nov. 10, 1898.

the conversion ratio 71·8 per cent., which corresponds exactly with the tabular value.[51] In some three-phase 200-kilowatt machines, now in Brooklyn, N. Y., the pole-breadth was 64·7, the conversion ratio 63·3 per cent.—here again somewhat below the tabular value. These empirical values, along with curves plotted from Kapp's table, are plotted in *Fig. 5*.

Pole-breadth is not, however, the only thing that affects the conversion ratio, as seen by the curve in *Fig. 6*, which is plotted from values given by Thompson in the article referred to, for a converter running with a *continuous current primary* and two-phase secondary at the constant speed of 1,200 revolutions per minute, and different excitations. In this case the pressure ratio rose from 60·8 per cent. to 71·0 per cent. during the excitation of the field, a variation of 16·6 per cent.

It is easy to see that such a rise would be due on account of armature reactions, which would, on account of excessive current-lag, be proportionately larger at feeble excitations, and thus tend to scatter the field. Such reactions have also an important effect in another direction, which will be pointed out under the head of Hunting; in both cases the remedy is to strengthen or "stiffen" the field. The dephasement of the impressed and counter-electromotive forces would also cause an apparent rise in the conversion ratio.

A remarkable example of an effect of the opposite character, of reactions upon the conversion ratio, is also given by Thompson in the same article. In this case a four-pole 55-kilowatt three-phase transformer—the same as that already referred to, page 46—ran synchronously without any excitation, but with a large backward lead of the secondary brushes, taking in three currents of 155 virtual ampères at 100 virtual volts and giving out 46 continuous current ampères at the *same voltage!* Needless to say, we cannot fully

[51] This machine is put down by Professor Thompson as a three-phaser, which appears to be certainly an error (*Ibid.*, p. 710). There is nothing to account for such a high pressure ratio, in a three-phase machine, whereas all the other cases show values below the tabular value.

analyze this case, at least without full data, but we may point out the following considerations:

(1) As the *D C.* pressure of the machine with its normal field was 300 volts at 370 revolutions per minute, in this case (at 627 revolutions per minute) it would have been 400 volts, and the induced field-strength was therefore only one-fourth the normal.

(2) The discrepancy between the ampères on the two sides of the machine shows the primary current to have been nearly all wattless.

(3) Owing to the weak field there was a *lag* in the primary current, and this lag was practically 90°.

(4) This 90° lag, with its accompanying enormous wattless current, induced in the pole-pieces a field of considerable strength, and with a minimum of lateral distortion.

(5) In like manner the large backward lead of the secondary brushes reacted to produce and maintain a constant field in the pole-pieces, also with little lateral distortion, and the two slight distortions neutralized each other.

(6) The primary and secondary circuits thus combined to produce a concentrated field, though weak.

(7) *Theoretically*, the only way in which the primary could be raised to equality with the secondary pressure would be to expand the tops of the curve of *Fig. 4* to one-half the circumference, the sloping sides becoming vertical, so that the curve takes the form shown in *Fig. 7*; in other words, the flux is concentrated in a mere point.

(8) While of course this could not happen in practice, such concentration may be accountable for a large part of the rise, while armature losses and dephasement of the impressed and counter-electromotive forces would easily make up the difference.

(9) We might otherwise or additionally account for the excess primary virtual pressure by the presence of harmonics such as, for instance, a large tertiary harmonic, causing the curve to assume a double-peaked or crater-like form.[52]

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[52] As shown, for instance, by Steinmetz, Discussion on "Alternating Current Curves," *Figs. 3* and *4*, *Trans. A. I. E. E.*, V. 12, pp. 476–477, June 27, 1895.

In connection with this machine it is worth while to remark further, as indicative of the very great flexibility of the system, that it would, according to Thompson, "run as a synchronous motor delivering continuous current sparklessly, *with or without* excitation of the field-magnet, and with brushes set at zero, or set with either a large forward or large backward lead."

Pressure Adjustment.—One of the disadvantages of the one-coil transformer, for any number of phases, is that it transforms up instead of down, and, in addition, gives us uneven and awkward ratios. We are, however, by the means indicated above, page 45, enabled to adjust the relation within certain narrow limits. Thus, by properly shaping the pole-pieces we obtain for an alternating current ratio or two-phase with 180° phase-angle (to follow the selected terminology) the simple ratio $\frac{3}{4}$ or $\frac{4}{5}$, instead of ·707, as required by the sine law; and similarly we may bring the ratio ·612 of the three-phase connection up to $\frac{2}{3}$. This change was, in fact, made in the 55-kilowatt machine just spoken of, which originally had spreading pole-faces covering an arc of 72° on a 90° pitch, so that the pole-breadth was 80 per cent. Under these circumstances the conversion ratio was only 57·7 per cent., so that with a 300-volt secondary pressure, the primary pressure was only 173 volts. By cutting away the pole horns, however, until the pole-breadth was but 54 per cent. of the pitch, the conversion ratio was raised to 66·6 per cent., and the secondary pressure to an even 200 volts.

This method is, however, as will be observed, of very limited application. Another, admitting of more flexibility, was first described in Blackburn and Spence's English patent of 1895,[53] and subsequently by Heldt in this country.[54] It consists, briefly, in winding additional coils upon the armature between the points of connection with the closed coil winding and the slip-rings. This lengthens the *A C* or polyphase turns, and hence increases the *A C* or polyphase pres-

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[53] No. 11,153.

[54] *Elec. World*, V. 28, p. 68, July 18, 1896.

sure, without affecting that in the *D C* circuit. In a monophase circuit such a coil need be interposed on only one side of the closed coil winding; in polyphase circuits one such coil is interposed for each slip-ring connection. The additional windings thus added are necessarily of the open coil or star type, as shown in the Van Depoele patent described above (Plate XVI). This winding, as adapted to a three-phase rotary, is substantially shown in *Fig. 3* of Plate XIX. The whole amounts to a star and mesh winding. In this manner the conversion ratio may be brought up to any desired figure. Apparently even very high pressures, as those direct from the transmission line, without any intermediary stationary transformers, might be used on such a machine properly wound; but Mr. Heldt prefers only to bring the alternating or polyphase pressure up to equality with the *D C* pressure. It is to be observed in this connection that this feature really introduces the elements of a two-coil transformer, because no direct current, or secondary current, passes through the star or auxiliary winding; on the other hand, the primary alternating or polyphase current is no longer sufficient to neutralize the other in its heating effects in the mesh or main winding, to the full extent possible in the simple rotary. With a high voltage ratio, in fact, practically the whole advantage of the one-coil transformer, which is based on such current neutralization, would be lost, and we might as well build the machine with the coils entirely separate, and so get the added advantage of more perfect protection from high-pressure leaks. Still, the device is undoubtedly an ingenious and highly useful one, furnishing, as it does, the only general solution of the problem of pressure transformation in a one-coil transformer that we have.

Shifting the brushes as a means of altering slightly the conversion ratio may prove useful as a temporary expedient in some cases, for, as we have already seen, the same difficulty as regards sparking is not inherent in the rotary transformer as is the case with nearly all other forms of direct-current machinery. But the same cause which prevents sparking, to wit, the automatic self-adjustment of the alter-

nating lag or lead and its reaction upon the field, *ipso facto* preserves or tends to preserve the conversion ratio constant; so that we cannot hope, in general, to accomplish very much by this plan. In the unusual case mentioned on page 47, the *A C* pressure was in this way brought up to virtual equality with the *D C*, as we have seen.

Other modes of varying the conversion ratio will be treated under the head of

Pressure Regulation.—The question of pressure regulation for variations of load in a rotary transformer is one of great importance; though not more so, perhaps, than in a stationary transformer, and probably easier of a satisfactory solution. Yet it cannot be said that a satisfactory solution has as yet been reached. The case here is much the same in character as that already treated in the similar case of dynamotors (page 16). A number of devices have been invented for this purpose, differing according as the machine was used as an alternating-direct or direct-alternating current transformer.

As already stated on page 228,* the alteration of the field excitation in a dynamotor produces no effect on its conversion ratio, and neither does it affect the armature losses for a given load on the machine. Not so the latter, however, with the rotary transformer, for here we encounter one of those peculiarities of alternating currents which place this machine on a different footing from the dynamotor. Although we do not, in the rotary transformer case, affect the real pressure ratio, we do affect the virtual or *apparent* pressure ratio indirectly, by increasing or diminishing the armature losses. In fact, as we shall hereafter point out, the latter are increased or diminished according as the armature current is thrown out of or brought into phase with the pressure in the primary supply mains. Now, as heretofore shown (page 279†), in order to cause the current to lead or lag behind the E.M.F. in the supply mains, we have only to give the machine a greater or less degree of excitation than that sufficient to generate an equal counter-

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*March number of this *Journal.*

† April number of this *Journal.*

E.M.F. Hence, any device which will cause the current to lead or lag behind the E.M.F. in the supply mains during light loads, so as to cause a relatively large armature loss, and bring it into phase there with as the load is thrown on, will thereby equalize the armature losses for all loads and so render the pressure at the *D C* terminals constant. A device for this purpose has been patented to Steinmetz,[55] and consists in a field rheostat combined with a solenoid or other governor adjusted to strengthen the fields as the load increases, thus bringing the current more nearly into phase and decreasing the field-losses—the machine being run at no load with deficient excitation and consequent lagging current.

We see, therefore, that while the real conversion ratio or a rotary transformer remains the same under any excitation—neglecting for the moment the effect of armature reactions—its *apparent* conversion ratio is affected by changes in excitation, due to the consequent differences of phase between the impressed and counter-electromotive forces. But increasing the field-strength will not, as in a continuous current machine, increase the apparent primary voltage indefinitely, but only until the impressed and counter-electromotive forces have come into phase; after which the ratio diminishes again. A simpler and obvious mode of effecting the same thing is merely to compound or wholly wind the machine with a series field-coil from the secondary circuit.

It has been also suggested that transformers be made with a large magnetic leakage, so that the machine, being overexcited at no load, causing the current to lead, a greater alteration of the angle of lead will be occasioned on throwing on the load. Such leaky transformers have been made with an apparent conversion ratio which could be made to vary to the extent of 1 : 2, but it has been stated by their author[56] that they have no *regulating* qualities at all.

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[55] No. 543,907, of August 6, 1895.

[56] W. M. Mordey, in discussion of Thompson's paper, *loc. cit.*, pp. 699 and 711.

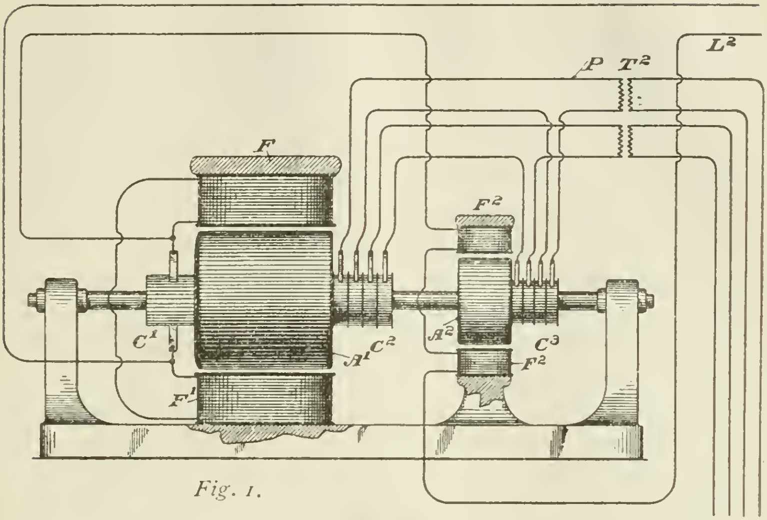

Fig. 1.

Fig. 2.

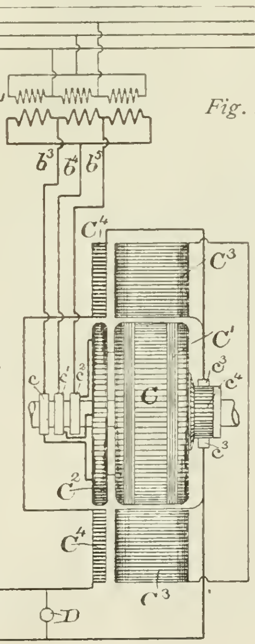

Fig. 3.

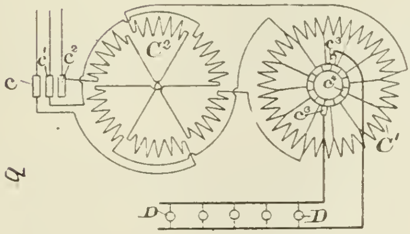

PLATE XIX.—Pressure regulation. *Fig. 1*, Scott's method (1894). *Figs. 2* and *3*, Thomson's method (1896).

Another mode of regulation is to increase or diminish the impressed primary E.M.F. by a reactance coil in series with the primary circuit. This may be combined, if a wide range of pressure is desirable, with a variable and adjustable number of coils in the secondary winding of the stationary transformer.[57] All these modes of regulation so far described, it is to be noted, correspond precisely to the common reactance coil method of regulating stationary transformers, and are unsatisfactory in being, so to speak, only "negative" modes—their essential characteristic being the introduction of a defect at the start, and its greater or less elimination according as the machine is more or less used.

A method founded on better principles, although open to the criticism of expense and complication (just as in the case of the dynamotor), is that shown in *Fig. 1* of Plate XIX,[58] in which a booster is used. This booster is not introduced into the secondary or *D C* circuit, but into the primary circuit; but it is excited by a coil in series with the secondary circuit. Although in series with the two-phase primary of the main machine, it is driven by that machine as a motor; thus the machine is made to raise its own pressure with increase of load. The primary pressure being raised, of course the secondary is raised in proportion.

A still further and great advance on the foregoing is the Thomson[59] plan, shown in *Figs. 2 and 3* of the same plate, involving a partial separate winding in the primary circuit, on a separate but juxtaposed armature core, and excited by separate fields in series with the secondary circuit. This is really an adaptation of his improved dynamotor as shown in Plate XI.

The methods of regulation thus far spoken of are limited to *A C-D C* working. For the reverse method, with a *D C* primary circuit, wholly different methods may be employed. In fact, the chief aim to be achieved is not a constant pressure in the secondary circuit, but a constant speed, because

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[57] As shown by Lamme's patent, No. 606,560, of June 28, 1898.

[58] Scott's patent, No. 515,885, of March 6, 1894.

[59] Patent No. 563,895, of July 14, 1896.

the motors driven thereby will run synchronously with the transformer. Now, on any increase of load the speed of the latter will tend to diminish, just as in any continuous-current motor. This may be avoided by weakening the field-strength at the same time, and if an exciter is mechanically driven by the transformer and at proportionate speed therewith, it will diminish the field excitation on any diminution in speed, and so accomplish the end in view.[60] It is obvious that by this method the secondary pressure must be subject to wide variations.

Another mode by the same inventor is to place reactance coils in shunt with the secondary circuit. It is clear that this is open to the same objections as the use of reactance coils in the other cases above mentioned, but *a fortiori.*

From the discussion which took place on Professor Thompson's paper already cited, it appears that the difficulty of securing good regulation—taken with the tendency to hunt, which will be spoken of later—is the prime factor which has caused European engineers to look with dissatisfaction on the rotary transformer, and its place to be taken by motor-generators.

Current Relations.—The flow of current in a rotary transformer has been investigated mathematically by a number of writers, in particular by Kapp[61] and by Woodbridge and Child,[62] and Professor Thompson in the paper above referred to has treated the subject graphically. A detailed exposition of the mathematical theory would be beyond the scope of this paper, but the main principles will be given.

The easiest mode of treating the subject is that of superposition. So far as electromagnetic effects are concerned, such as armature reactions, the result of superposition is nearly the same as the sum of the effects of the two currents, so that we may for practical purposes consider the reactions upon each current separately, as if it were the only one in the field. But the case as respects the ohmic or re-

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[60] Lamme's patent, No. 606,015, of June 21, 1898.

[61] *Elektrotech. Zeitsch.*, V. 19, p. 621, Sept. 15, 1898.

[62] *Elec. World*, V. 31, p. 12, Jan. 1, 1898.

sistance effect stands differently, for, as is easily seen, the resistance to two opposite currents flowing in a conductor is that of their difference and not the sum of their joint resistances. We need, therefore, to find what this resultant value is for each conductor in the armature, and for each position of that conductor.

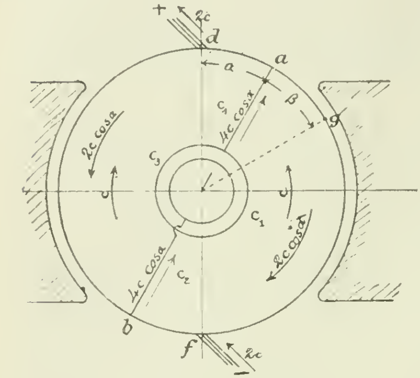

Fig. 1.

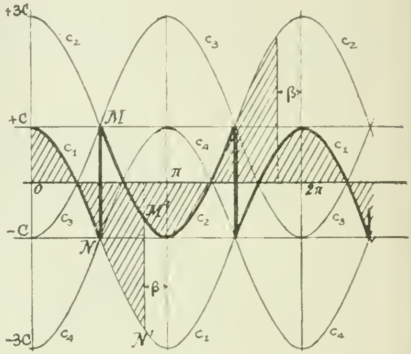

Fig. 2.

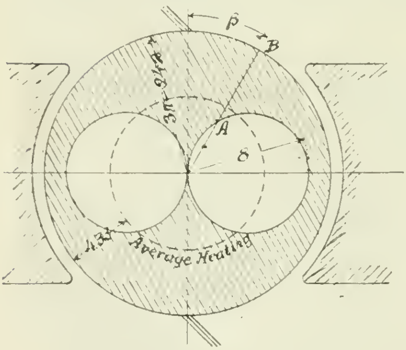

Fig. 3.

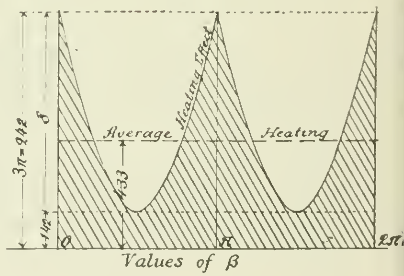

Fig. 4.

PLATE XX.—Armature currents and heating in the single-coil transformer.

Taking first the simplest case—that of a two-segment (monophase) armature, having a sinusoidal current wave, no phase-displacement, and 100 per cent. efficiency; if E is the $D\,C$ E.M.F. and $2\,C$ the $D\,C$ current, the output of the machine is $2\,CE$. The maximum pressure on the alternating side being also E, the maximum current on that side is

$4\,C$, so that the output on this side, which is one-half their product, may also be equal to $2\,C\,E$, the output of the $D\,C$ side. This maximum current on the $A\,C$ side occurs when the armature is in the position of maximum pressure on that side—that is, when the line of ring-connections is in the position $d\,f$ (see Plate XX, *Fig. 1*). At this moment, then, a net current equal to $2\,C - C = C$ is passing downwardly through both halves of the armature, supposing the $D\,C$ to be the generator side, and the upper brush positive, as shown. Now, when the armature has passed through an angle α and the line of ring-connections is in the position $a\,b$, the alternating currents in each half will be $2\,C \cos \alpha$, and each vertical half of the armature will be divided into two parts by the line $a\,b$, so that we have for the net current in each of the four parts,

in $d\,a$,	$c_1 = - C\,(1 - 2 \cos a)$,
in $a\,f$,	$c_2 = + C\,(1 + 2 \cos a)$,
in $f\,b$,	$c_3 = + C\,(1 - 2 \cos a)$,
in $b\,d$,	$c_4 = - C\,(1 + 2 \cos a)$.

These curves are plotted in *Fig. 2*. The current in any individual conductor g making an angle β with the division line $a\,b$, and an angle $a + \beta$ with the commutation line, will therefore be, for any value of a,

from O to $\pi - \beta$,	$c_1 = C\,(2 \cos a - 1)$,
from $\pi - \beta$ to π,	$c_2 = C\,(2 \cos a + 1)$,
from π to $2\,\pi - \beta$,	$c_2 = C\,(2 \cos a + 1)$,
from $2\,\pi - \beta$ to $2\,\pi$,	$c_1 = C\,(2 \cos a - 1)$.

In one-half revolution the total work lost is

$$w = r\left(\int_0^{\pi - \beta} c_1^2\,dt + \int_{\pi - \beta}^{\pi} c_2^2\,dt + \int_{\pi}^{2\pi - \beta} c_2^2\,dt + \int_{2\pi - \beta}^{2\pi} c_1^2\,dt\right)$$

$$= \frac{C^2\,r}{2\,\pi\,n}\left(\int_{2\pi - \beta}^{\pi - \beta} (1 - 2 \cos a)^2\,da + \int_{\pi - \beta}^{2\pi - \beta} (1 + 2 \cos a)^2\,da\right),$$

remembering that $da = 2\pi n\, dt$, if n is the number of revolutions per second. Continuing the reduction,

$$w = \frac{C^2 r}{2\pi n}\Big[\int_0^{2\pi}(1 + 4\cos^2 a)\, da$$

$$+ 4\Big(\int_{\pi-\beta}^{2\pi-\beta} \cos a\, da - \int_{-\beta}^{\pi-\beta} \cos a\, da\Big)\Big]$$

$$= \frac{C^2 r}{\pi n}(3\pi - 8 \sin \beta).$$

This equation is exhibited to the eye in *Figs. 3* and *4*.

This is the work or heating effect for one conductor only, or per unit length of the armature periphery, according to the meaning we give to r. To find the whole work we integrate this equation for the whole circumference, or, as β is limited to values between 0 and π, we have for one revolution of the armature,

$$W = 2\int_0^{\pi} w\, d\beta$$

$$= 2\frac{C^2 r}{\pi n}\int_0^{\pi}(3\pi - 8 \sin \beta)\, d\beta$$

$$= 2\frac{C^2 r}{\pi n}(3\pi^2 - 16)$$

$$= 8{\cdot}664\frac{C^2 r}{n}.$$

The power consumed, at n revolutions per minute, is

$$P = \frac{2C^2 r}{\pi}(3\pi^2 - 16) = 8{\cdot}664\, C^2 r.\text{[63]}$$

The average heating per unit periphery is

$$\frac{W}{2\pi} = 4{\cdot}332\frac{C^2 r}{\pi n},$$

[63] This value is the same as that given by Kapp, but the mode of reaching it is not quite the same. There are two advantages of the method given above: first, it is simpler, although involving a double integration; and, second, it gives the heating in each part of the armature, which Kapp does not consider at all, but which is a matter of great importance, because we cannot properly average up our heating all over the armature, and then make the average equal to that allowed in an ordinary dynamo, when some of the coils are heated more than twice that average.

and it is plotted in *Figs. 3* and *4* on the same scale as w $\left(\frac{C^2 r}{\pi n} = 1\right)$.

We now pause to consider briefly some of these results.

From *Fig. 2* we see that the current in an individual coil changes abruptly at the brushes by an amount $2\,C$, and that it either rises to its highest value just before reaching the brushes (as shown by the shaded area in *Fig. 2*, for which $\beta = 30°$), when it abruptly falls, or else is suddenly raised at that point and falls off gradually, depending on whether β is less or greater than 90°. For all values of β between $\beta = 60°$ and $\beta = 120°$, the current has four zero points, independently of reversal at the brushes, during a revolution; for other values, only two such points. The value $\beta = 90°$ is shown by the heavy line. We can see in a general way that the area of the curve (and hence the heating effect) increases from $\beta = 90°$ in both directions, since the change is accomplished by simply moving the line $M\,N$ along the curve (as for instance, to M′ N′ for $\beta = 30°$).

Fig. 3 shows the meaning of the equation for w on page 358. The circle forming the outline of the armature is drawn equal to $3\,\pi$ on a scale of

$$\frac{C^2 r}{\pi n} = 1,$$

to represent the first term of w, and within this are inscribed two circles of diameter 8 each. It will be clear that the portion $A\,B$ of any radius will represent the corresponding average heating of a coil making the corresponding angle β with the line of slip-ring connections $a\,b$, *Fig. 1*. The dotted circle shows the average heating of all the coils, which is the distance between the circumference of this circle and the outer one.

The same thing is plotted rectilinearly in *Fig. 4*. From these figures and the equation for w, we see that the maximum heating occurs in the coils or conductors lying adjacent to the slip-ring line, and that this heating is equal to

$$3\,\frac{C^2 r}{n},$$

or about 6·62 times that of the coils in quadrature with it, and 2·18 times the average for the whole armature.

For other distributions of the magnetic field, to wit, with pole-breadths equal to ⅔ and ½ the pole-pitch, and a uniformly distributed magnetic flux, Kapp finds the heating to be only 92 and 78 per cent., respectively, of the heating with sinusoidal wave. This shows a distinct advantage of concentrating the field, as might in fact be inferred from the rise in *A C* pressure which accompanies it.

The investigation of the three-phase and four-phase connections follows the same general method, and we need not pursue it in detail. It will suffice to state the results arrived at by Kapp:—

ARMATURE HEATING ($\div C^2 r$), FOR CONSTANT OUTPUT.

	Sine-law.	Pole-width ⅔.	Pole-width ½.
Monophase	8·66	7·97	6·79
Three-phase	—	3·28	3·02
Four-phase	2·55	2·24	2·20

As might be expected from the fact that the energy supplied from a monophase circuit is intermittent, while that from a polyphase circuit is constant, the armature heating is more than cut in two by a three-phase connection, and a further large reduction is shown by a four-phase connection. As the E.M.F. reaches its maximum at three points of a revolution in the one case, and at four in the other, there is less chance for a large fluctuation in the current. The virtual current is besides, of course, much less in proportion as the phases are multiplied, as shown by the following table, deduced from that on page 41 on the assumption of 100 per cent. efficiency:

Number of Segments.	Armature Current in Each Segment. Maximum.	Virtual.
Continuous	50	50
2 (monophase)	100	70·7
3	77·0	54·5
4	70·7	50·
6	66·7	47·2

Kapp further investigates the case of phase-displacement, which of course increases the current, but only, as he finds, in proportion as it alters the distribution of the flux.

The effect of a leading or lagging current is the same, and is very noticeable if it exceeds a small angle. Some values are given below under "Output."

The above mode of investigation, however, is imperfect, as it takes no account of armature losses, which ordinarily take up 5 to 10 per cent. of the power, and play a necessary part in all machines,—together with the effects of inductance and field reaction which they imply, and which are not neutralized by any current on the *D C* side.

Output.—The proportionate output of a rotary transformer to that of a *D C* dynamo is easily found from the above figures for armature heating. Assuming an even average heating for all the armature coils (which, however, as we have seen, is in single-phase machines very far from being the case), we may adopt as a measure of output an equal heating of the armature. Now the heat lost in a *D C* dynamo, whose current is 2 C_1, is $2 \pi C_1^2 r$, and from the equation for P (page 58) we therefore have for the output of a monophase rotary transformer:

$$O = \frac{C}{C_1} = \sqrt{\frac{\pi^2}{3 \pi^2 - 16}} = \cdot 85$$

In the same way Kapp gets for pole-breadths $m = \frac{2}{3}$ and $m = \frac{1}{2}$ the pitch the outputs ·88 and ·95 respectively, showing how great is the effect on the output of concentrating the flux. Treating the polyphase machines the same way, we get the following table of outputs, in percentages of the same machine considered as a *D C* generator and rotated by mechanical means:

	Sine-law.	Pole-breadth $m = 2/3$.	Pole-breadth $m = 1/2$.
Monophase	85	88	95·
Three-phase	134	138	144
Four-phase	164	167	170
Six-phase	196	198	199

For $\cos \varphi = \cdot 9$ we get for a monophase machine in the last two cases 81 and 88 respectively; that is, the output of the machine is diminished by this amount of phase-lag to the extent of 8 per cent.

We see from the above table that, while the output of a monophase rotary transformer is 5 to 15 per cent. less,

that of a three-phase machine is 34 to 44 per cent. greater than that of the same machine mechanically driven; while the four-phase machine practically doubles the output of the monophase, and the six-phase that of the *D C* dynamo. We see here the great advantage, already referred to on page 281,* of doubling or otherwise increasing where possible the number of phases, and it has for this reason even been suggested [64] that the polyphase generator of the future will have as many armature coils as a continuous current machine, and that the line will be a cable composed of many insulated wires, each communicating with a separate armature segment on a rotary transformer at the delivery end. Unfortunately this arrangement would necessitate either an inordinate number of slip-rings or the awkwardness of rotating brushes, and the feasibility of keeping a large number of line-wires insulated from each other at high pressure seems at least doubtful. Some recent machines of the inductorium type, however, to be spoken of later on, actually proceed upon this principle.

It should not be forgotten that from these figures should be deducted a very considerable percentage to allow for armature losses, which have not been taken into account. Attention is also called to the fact, pointed out by Prof. Carus-Wilson,[65] that the limiting load of a rotary transformer depends not simply on the safe limit of heating which may be allowed, but on the load at which the machine will fall out of step. This, too, depends on the heat-loss in the armature.

In an actual case,[66] it was found that a machine connected up for both monophase and three-phase currents gave an output 1·7 to 1·8 greater in the latter case than in the former.

Efficiencies.—Under this head will be given some actual results, as theory does not appear to have reached that per-

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* April number of this *Journal.*

[64] *Electrician* (London), V. 42, p. 229, Dec. 9, 1898.

[65] Discussion of Thompson's article, *Jour. I. E. E.*, V. 27, p. 713, Nov. 24, 1898.

[66] *Ibid.*, p. 717.

fection in treating the rotary transformer that it has in treating the dynamo—as may be surmised from the imperfect method adopted in finding heating effects.

The following table has been compiled from data given either by Thompson, in the paper already referred to, or by others during the discussion of that paper; except the last, which relates to the transformers of the Pittsburgh Reduction Company, of Niagara Falls, and is given by Emmet:[67]

Maker.	Authority.	Size, K. W.	Phases.	Frequency.	Efficiency, p. c.
—	Thomas	—	Alt'g	—	75
—	"	—	3	—	92
General Elec Co.	Thompson	900	3	25	(93–95)
Elec. Const'n Co.	Mance	45	3	42	90
(Dublin R'ys.)	Hobart	200	—	30	91–92[68]
—	"	—	—	—	90[68]
—	Parshall	900	—	—	95
Brown, Boveri & Co.	Thompson	30	4	40	90
Alioth Co.	"	100	4	45	90
General Elec. Co.	Emmet	400	4	25	94

No. 3 gives only the efficiency stated in the manufacturers' guarantee, so that it may be practically disregarded. Nos. 5 and 6 include the stationary transformer, so that the efficiency of the rotary alone would be several per cent. higher in these cases.

The above results cannot be considered more than provisional, as we have no exact information as to how they were obtained. We see merely in a general way that the efficiency of a polyphase rotary transformer, by these figures, varies from 90 to 95 per cent. In practice we may doubtless be more nearly correct in discounting them to some extent.

The one test given for an *A C* transformer shows, what might be expected from the facts brought out under "Current Relations" and "Output" (pages 360 and 361), that its efficiency is much less than that even of a three-phase trans-

[67] *Trans. A. I. E. E.*, Vol. 12, p. 483, June 28, 1895.

[68] Including stationary transformers.

former. But between three-phase and four-phase machines we cannot find any appreciable difference.

As we must generally compound with these figures the loss in stationary transformers, we should probably get as a result but about 85 per cent. efficiency in the general case—little higher than that of a motor-generator. This cannot be called a satisfactory efficiency for what is in effect a single (though not a simple) transformation. As little more can be expected of the one-coil machine than we can now get from it, this may be taken as pointing us in another direction.

Regarding costs, according to Hobart,[69] taking the cost of a motor-generator at 100, we may consider the rotary transformer to cost, including stationary transformers, about 70 to 90 per cent., according to the efficiency expected of them, so that some saving is made by using the transformer, though less than we should reasonably have expected. The repair-bill will also be less, of course, for the transformer.

To sum up, where good regulation on a very variable loading is required, as in lighting service, the diminished cost of the transformer will probably not offset the better regulating qualities of the motor-generator.

Hunting.[70]—There is one disease which appears to be common to all machines which use alternating or polyphase current, and run on the synchronous principle, and that is hunting. So much has been said on this subject that no treatment of rotary transformers, however brief, would be complete without some mention of it. What has been said and done, however, has been more in the line of opinion, experience and experiment than of actual or theoretical investigation. The rotary transformer appears to be particularly liable to this affection, and the subject comes

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[69] *Jour. I. E. E.*, V. 27, p. 708, Nov. 24, 1898.

[70] There are at least five synonyms for this word which appear to be used indiscriminately—*surging*, *seesawing*, *racing*, *pumping* and *drifting*. I really cannot see why the art requires six words which mean all the same thing. Perhaps the first two most appropriately express the phenomenon, but I have selected "hunting" as being the term in most common use.

up for its share of discussion wherever the rotary transformer is discussed. In fact, hunting in its ordinary form, meaning a swaying or fluctuation of the speed from one extreme to another, with accompanying fluctuation in the secondary pressure, and frequently violent sparking at the brushes, has been found so serious a defect in some cases as to necessitate the replacement of the offending machine by a motor-generator. This was the case in Professor Mengarini's Tivoli-Rome installation.[71] (These machines were, however, two-coil single-phase rotaries.) The defect appears to be particularly prominent in the larger size transformers, and especially where run in parallel. Another puzzling case, according to Professor Thompson, is "when two converters are arranged at the two ends of a long three-phase line for the purpose of feeding continuous currents from one point to another."

The causes of hunting are not in all cases to be ascertained with certainty. A case is related[72] where two transformers could not be induced to run in parallel satisfactorily and to equalize the load, and "the whole trouble was found to lie eventually with the brushes and the unequal resistance they offered at their rubbing surfaces." Still the causes ascribed may be in general grouped under four heads, viz.:

(1) Uneven speed of the steam-engine or other prime mover.

(2) Weak or yielding fields and the consequent armature reactions.

(3) Dissimilarity of the E.M.F. curves of the different machines.

(4) Too much self-induction.

If the fault lies in the steam engine at the distant end of the line, of course the only proper remedy is to correct it at that point. Fluctuating speed of the prime mover will invariably produce its equivalent all over the distribution system.

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[71] See discussion of Professor Thompson's article, *loc. cit.*, p 712.

[72] *Ibid.*, p. 700.

The most probable and most usual source of the hunting is no doubt a weak and especially a yielding magnetic field. Easy distortion of the field gives a wide latitude for speed fluctuations without the machine's losing synchronism, and the magnetic lines, pulled as it were, first in one direction and then in the other, act like elastic cords to increase the swaying movement, until, in some cases, the armature finally breaks away from them, that is to say, loses synchronism and refuses to run. The alternate distortion of the field easily explains the sparking at the brushes.

The remedy for this defect is to stiffen the field—both strengthen it, and by properly designing the pole-pieces prevent its distortion. The exciting coils should be placed on their extremity, as near as possible to the surface of the armature. Another remedy is to surround the pole-pieces at their extremities with a short-circuited ring or coil of copper, which may, if desirable, cover the pole-faces also. This acts as a damper to prevent distortion. It may occasion, however, considerable loss of power and a lowering of efficiency from 1 to 3 per cent.

Dissimilarity in the curves of electromotive force is a hypothetical rather than known cause of hunting. It does not appear to bear any necessary relation to the subject, however, as machines having wholly different and very irregular curves will often work together without any difficulty.[73] Steinmetz has suggested, however, that in three-phase machines the triple harmonic, which is the most important, will coincide in phase with and thus annihilate each other, whereas in a four-phase machine they will combine in a rotary effort which tends to revolve the machine backward at triple synchronism. It is not apparent how this could affect the speed of a synchronous machine.

The self-induction of the circuit is a point which may or may not have importance, but usually, no doubt, its effect is too insignificant to be considered, as in the case of alternating dynamos.[74]

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[73] See, for instance, Steinmetz in *Trans. A. I. E. E.*, V. 12, p. 498.

[74] See Thompson, "Dynamo Electric Machinery," 4th Ed., p. 699.

A general remedy for hunting is to increase the angular momentum of the rotating part of the machine, and thereby make a variation of speed more difficult. This is the same remedy as increasing the flywheel capacity on an engine.

The subject need not here be treated with greater detail, but enough has been said to indicate it as a line requiring the attention of investigators and inventors.

Theory of the Two-coil Transformer.—The two-coil transformer does not need detailed treatment separately from the one-coil transformer, with regard to the points above considered, excepting in its current relations, output and efficiency; in other respects it is essentially identical with the latter. As will be evident, the total armature heating effect for the same output will be very much increased, and the output and efficiency much diminished, in relation to those of the single-coil machine, as there is no neutralization of armature currents.

Supposing, as before (page 56), the output of the $D\,C$ side to be $2\,C\,E$, the armature heating will be $2\,C^2\,r$, as above explained. The input of the $A\,C$ side of a monophase machine, at 100 per cent. efficiency, is then also $2\,C\,E$, and its maximum current $4\,C$—supposing the maximum pressure to be the same as on the $D\,C$ side—so that the heating effect in each half of the armature will be

$$\frac{(2\,C)^2}{2}\,\pi\,r,$$

and for the whole armature, $4\,\pi\,C^2 r$. Adding these together, we get for the total heating effect, $6\,\pi\,C^2\,r$, or three times that of the machine when run as a $D\,C$ generator at the same output, and

$$\frac{3\,\pi^2}{3\,\pi^2 - 16} = 2{\cdot}17$$

times that of a single-coil rotary of the same output. For the output at equal armature heating, we have, as on page 361,

$$O = \frac{C}{C_1} = \sqrt{\frac{1}{3}} = {\cdot}577$$

or little more than half that of the same machine run as a $D\,C$ generator. The efficiency will be correspondingly lowered.

For polyphase machines, taking the current values given on page 60,

3-phase, $$W = \left(\frac{1{\cdot}54^2}{2} \,.\, 2\,\pi + 2\,\pi \right) C^2 r = 4{\cdot}37\,\pi\, C^2 r;$$

4-phase, $$W = \left(\frac{\sqrt{2}^{\,2}}{2} \,.\, 2\,\pi + 2\,\pi \right) C^2 r = 4\,\pi\, C^2 r;$$

6-phase, $$W = \left(\frac{1{\cdot}334^2}{2} \,.\, 2\,\pi + 2\,\pi \right) C^2 r = 3{\cdot}79\,\pi\, C^2 r.$$

Proceeding, we obtain the following table for the two-coil rotary transformer:

Phases.	Heating for Given Output.			Output for Given Heating.	
	$\div C^2 r.$	Ratio to		Ratio to	
		DC gen'tor.	1-coil R. T.	*DC* gen'tor.	1-coil R. T.
Single	18·85	3	2·17	·577	·68
3	13·75	2·18	(3·7)	·677	(·52)
4	12·57	2	4·94	·707	·450
6	11·91	1·89	—	·729	—

The above values are calculated on the assumption that the pressure bears the same ratio on the two sides as in a one-coil transformer. This, however, from the well-known dynamo-formulæ, cannot affect the result.

It will be perceived that the superiority over the two-coil machine rapidly increases as we increase the number of phases. The output of the two-coil machine increases very slowly as we increase the number of phases, and can, of course, never equal that of the same machine as a *D C* dynamo; while the one-coil machine may have an output far above the latter.

For this reason also the efficiency of the two-coil machine, especially of the single-phase variety, is necessarily very low, and it is no wonder that those at the Tivoli-Rome installation were taken out (see page 365.) They have, however, the great merit of dispensing with stationary transformers. but in this respect they are inferior as a class to the type we shall next consider.

[*To be continued.*]

ELECTRICAL SECTION.

Stated Meeting, held December 20, 1900.

ELECTROCHEMICAL ACTION.

BY C. J. REED, Member of the Institute.

Chemical Energy.—In every chemical change, whether it be one of combination, dissociation, or substitution, there is a transformation of matter and a simultaneous transformation of energy. The changes in matter may all be determined by means of the balance, which enables us to measure the masses affected. The transformations of energy require for their determination, in addition to the balance, the aid of some instrument for measuring the energy that passes into or out of the system during the chemical change. Heat, being the only form of energy into which all other forms may be converted without loss, is the form best adapted for such determinations. The calorimeter is, therefore, as necessary for determining the energy communicated to or from a system undergoing chemical change as the balance is for determining the masses affected.

The energy communicated (evolved or absorbed) in very many thermochemical reactions has been determined in the form of heat with great care. The precision of such determinations is not comparable with that of our most refined physical measurements, but greatly exceeds that of any other method of determining the energy of chemical changes. In a great majority of cases a heat method is the only available one for making any determination at all. It is possible, in some specific cases, by the aid of hypotheses, calculations, and a combination of experimental researches on different lines of investigation, to determine the energy of a chemical change in the form of electrical energy without a calorimetric measurement. But the results of this method are not certain and are always based upon assump-

tions. The method is also applicable to only a comparatively few cases.

By means of the data established calorimetrically we are enabled to study with advantage and reasonable certainty all other energy changes that may be concerned in chemical reactions without resorting to any theory beyond the assumption that energy can be neither created nor destroyed.

The chemical energy of a system capable of undergoing chemical change is measured by its power of doing external work in some form, as a result of the chemical reaction alone, and does not include the power the system may possess of doing external work through a change in its temperature. The chemical energy of a system, as thus defined, may be either positive or negative. It is always static or potential in form and must be treated as potential energy.

When a chemical system evolves energy, due entirely to internal chemical change, it may be restored to its initial condition, only by absorbing from without, in some form, energy equivalent to the chemical potential energy lost.

In this respect there is no difference between chemical potential energy and ordinary energy of position. In other respects, however, they are very different. Ordinary energy of position is determined by mass and distance, and is independent of the specific natures and physical conditions of the bodies concerned; while chemical energy depends upon the masses, the specific natures of the bodies composing the system and the physical condition of the system, but, so far as we know, is independent of distances. We might distinguish these two forms of potential energy by considering the one as *molar*, because it affects masses, and the other as *molecular*, because it affects molecules only.

The Communication of Chemical Energy.—There are two methods or processes by which the energy of a chemical change may be communicated to or from a system comprising chemically reacting bodies. In one of these processes the communication of energy is by radiation and conduction; in the other by conduction only.

When the energy of a chemical reaction is communicable, wholly or in part, by radiation, it is in the form of either heat or light and is always measurable as heat. When the energy of a chemical reaction is communicable by conduction only, it is in the form of electrical energy.* The quantity of energy communicated by a system in a chemical reaction is, of course, entirely independent of the form or manner of its transformation or transmission and depends only upon the difference between the chemical energy of the initial and that of the final state of the system.

We may divide chemical reactions, with reference to the manner in which their energy is communicable, into two general classes, *thermochemical*, or those in which radiant energy is communicable; and *electrochemical*, or those in which electrical energy is communicable. A particular system of reagents may be capable of producing only thermochemical action, or it may be capable of producing electrochemical action under particular conditions, or it may be capable of producing both reactions simultaneously and independently. But the same particle of matter cannot be simultaneously subject to both reactions. The energy of a given pair of ultimate particles or atoms cannot be communicated partly as electrical and partly as radiant energy without a second transformation of some kind. An atom or molecule cannot undergo a given chemical change by two processes simultaneously. An atom of zinc, for example, may combine with chlorine either thermochemically, communicating heat, or electrochemically, communicating electrical energy, but cannot simultaneously undergo both changes. This is a corollary of Faraday's discovery that a definite quantity of any substance in undergoing electrochemical change corresponds to the passage of a definite quantity of electric current.

Evolution and Absorption of Energy.—In thermochemical reactions heat (and light) may be either evolved or absorbed.

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* Chemical energy cannot be communicated by induction, and we are, therefore, not concerned here with the question of the nature of electric conduction, and for convenience we may consider electrical energy to be communicated by the wire or conductor carrying the current, rather than by the medium surrounding the conductor.

When heat is evolved at the expense of the chemical energy of a system, the reaction is said to be *exothermic.* When heat is absorbed with the accumulation of chemical energy within a system, the reaction is said to be *endothermic.* In electrochemical reactions electrical energy, instead of heat, is either evolved or absorbed as a result of the change. We have no specific terms, however, to indicate these particular kinds of reaction and it has been customary to speak of these changes also as exothermic and endothermic, although heat is in no way concerned. It is like speaking of the energy of a falling body as its *heat.*

In order to avoid this ambiguity and to state more exactly the relations of the various energy changes in electrochemical reactions, it will be convenient to specify the two kinds of electrochemical reactions by distinctive names. We shall, therefore, call those electrochemical changes, which evolve or generate electrical energy at the expense of chemical energy, *electrogenic* reactions, instead of exothermic, from ἤλεκτρον and γένεσις, signifying the generation of electrical energy; and those electrochemical reactions which absorb electrical and produce chemical energy, *electrothanic,* from ἤλεκτρον and θανεῖν, signifying the dying or vanishing of electrical energy. The processes corresponding to these transformations may be called respectively *electrogenesis* and *electrothanasis.*

A classification of chemical reactions, with reference to their energy changes, therefore, may be made as follows:

CHEMICAL ACTION	Thermochemical (energy communicable by radiation)	Exothermic (evolving heat or light)
		Endothermic (absorbing heat or light)
	Electrochemical (energy communicable by conduction only)	Electrogenic (evolving electrical energy)
		Electrothanic (absorbing electrical energy)

Thermochemical and electrochemical changes are strictly co-ordinate and both result in the same final products in

matter. They differ, as stated above, in the two distinct methods by which the energy corresponding to the chemical change is communicable and in the conditions necessary for the production of each of the two kinds of change. Zinc and chlorine, for example, may unite thermochemically and evolve heat, or electrochemically and evolve electrical energy, the resulting compound, zinc chloride, being the same in both cases. The reaction in the former case is exothermic and may result from the direct union of chlorine and zinc. In the latter, it is electrogenic and must result from a process of substitution.

Conditions of Thermochemical Action.—A thermochemical reaction requires only that a chemical system shall be brought to the proper conditions of temperature and pressure. The thermochemical reaction then takes place, generally throughout the system when the conditions and distribution are uniform, or locally at any point where the required conditions obtain.

Conditions of Electrochemical Action.—The conditions necessary for electrochemical action are very different from those required for thermochemical action. While a uniform mixture of the reacting bodies is always most favorable for thermochemical action, electrochemical action under such conditions is unknown. Electrochemical action takes place only at the bounding surface of a reacting body, and only at surfaces through which an electric current is either entering or leaving the reacting body. We have no evidence whatever of any species of electrochemical action affecting the chemical composition of the interior of a substance. A change of composition throughout the mass of a body may result, and in time generally does result in the case of liquid bodies, through the transportation of the products of electrochemical change, but the actual electrochemical changes occur only at the terminal surfaces.

Owing to this purely surface action in electrochemical change, it is necessary to classify and define electric conductors with reference to the manner in which an electric current may enter or leave them. Electrochemically there are two kinds of electric conductors, *electrodes* and *electrolytes*.

Electrodes.—If a direct, or continuous, electric current can be made to cross the junction of two different conductors without chemical action, the conductors are *electrodes.*

An electric current may, for example, be made to cross the junction of any two conducting chemical elements, such as the junction of two metals, or the junction of carbon and the metal, without any chemical change due to the current. Hence, all conducting chemical elements are electrodes. An electric current may also be made to cross the junction formed by a crystal of lead peroxide and a conducting element without chemical change. Hence, lead peroxide is also an electrode. Many metallic oxides and compounds *in the solid state* are electrodes.

Electrolytes.—If a direct, or continuous, electric current cannot be made to cross the junction of an electrode and a second conductor without chemical change, the second conductor is an *electrolyte.* All electrolytes are compounds and all conducting compounds in the liquid state, whether liquefied by fusion or solution, are electrolytes. There are many compounds which are non-conducting in the solid state, and which become electrolytes by fusion or solution. Some oxides, such as those of the alkaline earth metals, are nonconductors at low temperatures and become electrolytes at high temperatures without actually becoming liquid, although becoming somewhat softened.

Another condition necessary for electrochemical action is that at least one of the reacting substances shall be an electrolyte and that it shall undergo decomposition by a process of substitution or chemical displacement.

Electrochemical Systems.—An electrochemical system comprises two electrodes, each in contact with an electrolyte, the two electrolytes being electrically connected without the intervention of electrodes. Such a system is represented in *Figs. 1* and *2*, in which E and E' represent two electrodes, either of the same or of different material, and e, e' and e^2 represent electrolytes, all of which may be of the same or of different material. When the electrolytes are all of the same material they are usually regarded as a single electrolyte. There may intervene between the

two electrolytes, e and e', another single electrolyte, e^2, or any number of electrolytes in series, but no electrodes. While the electrolytes may all be of the same composition and apparently only a single uniform body, yet the system must be considered structurally as comprising two electrolytes in contact with each other and each in contact with its electrode, each electrode with its electrolyte constituting a distinct chemical system.

The electrochemical systems shown in *Figs. 1* and *2* are *inactive*, that is, incapable of electrochemical action in the condition shown. They may be rendered *active* by electrically joining the two electrodes, either directly or by the intervention of an additional or external conductor, provided the closed circuit so formed includes a source of electrical energy. Such a source of electrical energy may be contained in the

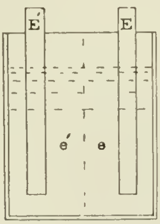

FIG. 1.

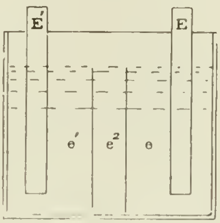

FIG. 2.

electrochemical system itself, or it may be included in the additional external conductor. If, in such a system, one electrode consists of zinc and the other of copper, each metal being in contact with a solution of one of its salts, the electrochemical system itself is a source of electrical energy. If the external conductor includes a dynamo, thermopile, or galvanic battery, the source of electrical energy is external to the electrochemical system. Evidently a closed circuit of this kind may include both internal and external sources of electrical energy.

The definition of an electrochemical system given above includes all known forms, whether they evolve or absorb energy and whatever may be the nature of the component parts of the system or of the external conductors used to render the system active, that is, to "close the circuit," and

whatever may be the source of the energy of the electric current.

The bounding surfaces of contact, at which the electrodes join the electrolytes, are always the loci of electrochemical action, and are the "poles" or terminals of the system.

Mixed Systems.—There may be several electrolytes mixed together in an electrochemical system, or several different electrodes in contact may be substituted for a single electrode. Under such conditions there are generally several different electrochemical reactions possible, all equally accessible to the same circuit. These different reagents are, by electrochemical action, successively exhausted in a particular order, as we shall see later.

An electrolyte, as already defined, is necessarily a compound body separable into two constituents, one of which undergoes chemical change at one terminal, and the other at the other terminal by separation out of the electrolyte. The constituents of an electrolyte (called by Faraday "ions"), in undergoing this separation, may separate in a free or isolated (uncombined) state, or they may separate from the electrolyte by combining with other bodies. In the latter case the separation and recombination with another body occur *in series* and simultaneously, the complete change constituting the electrochemical reaction. If, however, the constituents of an electrolyte are set free, that is, liberated, and subsequently enter into other combinations, such subsequent or secondary reactions are thermochemical and entirely independent of the electrochemical reaction. Such reactions are not in series with the electrochemical reaction. Secondary reactions may take place slowly or rapidly, depending on their nature and on the conditions present, but the speed of the electrochemical reaction is always dependent entirely upon the strength of the current, being unaffected by either temperature, concentrations or other conditions.

Kinds of Electrodes.—An electrode, as defined above, may be either a chemical element or a conducting compound. The zinc and copper electrodes of the Daniell's battery are

elementary, but the mass of lead peroxide, comprising one electrode of a lead accumulator, and the copper oxide, comprising one electrode of the Lalande battery, are examples of compound electrodes. An electrode is not to be confounded with the mechanical support which is sometimes used to retain it in position. An electrode of lead peroxide, for example, is generally, though not necessarily, supported in position by an adherent mass of metallic lead, which acts also as a conductor. The action of the lead peroxide electrode is exactly the same, however, whether the lead support is present or not. In reality only the active electrochemical surface belongs to the electrochemical system, the entire mass of the electrode, except that at the surface of electrochemical action, being only a conductor, through which the electrochemical system communicates with external bodies.

This may be more fully understood by reference to *Fig. 3*, which represents diagrammatically the series of conductors constituting a lead accumulator. *A* represents a mass of solid lead, *B*, a mass of spongy lead in electric contact with *A*. *C* represents an electrolyte (dilute sulphuric acid) in contact with *B*. *D* represents lead peroxide in contact with *C* and also with a second mass of lead, *E*. An electric current can pass through the electrolyte only by entering or leaving the conductors, *B* and *D*, the spongy lead at one terminal and the lead peroxide at the other. The current passes between the spongy lead and the conducting mass of inactive lead without electrochemical action. It also passes between the lead peroxide and the metallic lead without electrochemical action. Therefore, *B* and *D* are electrodes, according to definition, while *A* and *E* are mere conductors, which may also act as mechanical supports.

An electrode may, or may not, be a reacting component in an electrochemical system, but an electrolyte is always a reacting component and always undergoes electrochemical decomposition. In the lead accumulator the electrolyte and both electrodes are reacting components of the system, while in the Bunsen cell the zinc electrode and both electrolytes (H_2SO_4Aq and HNO_3) are the reacting components,

the carbon electrode undergoing no chemical reaction. The carbon electrode in this case may be replaced by any conducting element not affected by nitric acid, such as gold, platinum, or *aluminium* without materially affecting the electromotive force. With currents of very high tension the electrodes may even consist of air or other gases. Faraday decomposed solutions of sodium sulphate, using air electrodes and a static machine as the source of electrical energy, and had no difficulty in separating the acid and alkali at the terminals of the electrolyte.

Poles.—A *pole or terminal* of an electrolyte or electrode is the bounding surface which an electric current crosses in entering or leaving. The negative terminal of a conductor is the surface through which a current leaves, and the

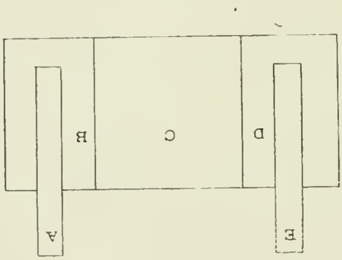

FIG. 3.

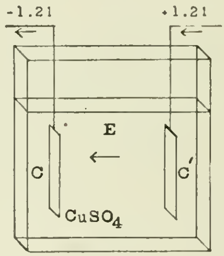

FIG. 4.

positive terminal is the surface through which a current enters.

Nature of Electrochemical Action.—Electrochemical action evidently cannot take place uniformly throughout the mass of the reacting system, as does thermochemical action, but only at separated and generally distant surfaces, which are always the terminals of an electrolyte. These surfaces must also be the terminals of electrodes or of other electrolytes. They may for convenience be called *electrolytic junctions.*

Whether these junctions, or loci of electrochemical action, are near together or remote from each other is quite immaterial, so far as the nature of the reaction is concerned. No chemical change whatever is produced in the body of the electrolyte, the changes in composition being produced

by the diffusion or mechanical convection of the products of electrochemical action, which are formed at the terminals of the electrolyte.

Changes in density are also produced in an electrolyte during electrochemical action. Changes in density are most marked near the terminals of an electrolyte, but extend throughout the electrolyte after prolonged action.

According to one theory these changes in the distribution and concentration of an electrolyte during electrochemical change are ascribed to the directive action of the electric current and the motion of electrified particles with different velocities. Such a supposition is entirely unnecessary, however, as the same result would follow from the changes in composition, if no current were present. That is, if the same chemical changes were produced at the terminals without the presence or agency of an electric current, the observed changes in density would still take place.

As there are always two separate terminals or electrolytic junctions in an electrochemical system, through which the electric current must enter and leave the electrolytic chain, in order to communicate electrical energy, there must necessarily, during electrochemical action, always be two separate and simultaneous chemical reactions, one at each terminal. These two reactions, occurring in series at the two terminals, are always of an opposite or different character, and are so related to each other that the reaction at one terminal is impossible without the reaction at the other.

An electrochemical system, or cell, as it is usually called, of the simplest type is shown in *Fig. 4*, in which the electrodes C and C' are plates of copper and the electrolyte E is a solution of uniform and definite density and temperature, containing a salt of the same metal, for example, copper sulphate. In this case both electrolytes are of the same material and both electrodes are of the same material. Such a cell is not capable of electrogenic action. That is, this electrochemical system is incapable of communicating any of its chemical potential energy in the form of electrical

energy.* Let us suppose, therefore, that the electrodes of this cell are connected by a conductor to form a closed circuit, which includes some external source of electrical energy capable of sending an electric current through the cell in the direction indicated by the arrow.

The electric current, in passing from the copper electrode C' into the solution, causes the copper to dissolve from this electrode by electrochemical action, forming copper sulphate. It has been determined by calorimetric measurements that a gram of copper, in passing into combination to form copper sulphate, always loses a definite quantity of chemical potential energy, numerically equivalent to 885 gram-calories of heat. The particles of copper evidently contain this energy while they remain a part of the copper plate. But after crossing the electrolytic junction and becoming copper sulphate, they no longer possess this potential energy. The inevitable conclusion is that this chemical energy must have been lost as such by the copper in the act of crossing the electrolytic junction between the copper electrode C' and the electrolyte, since, before crossing this surface, the copper has the energy of chemical separation, and, after crossing the junction, it has not the energy of separation. It is found that no heat is developed or absorbed at this junction, except that which

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* This does not imply that the system is incapable of giving up electrical energy at the expense of its heat, or of any other form of energy, except chemical, which it may possess. For example, if the circuit be closed by connecting the electrodes C and C' through any external, inert system of conductors, to which it is desired to impart electrical energy, we may abstract electrical energy from the electrochemical system by cooling one of its electrolytic junctions. An electric current would then flow through the circuit, passing from the copper to the electrolyte at the cold junction. The electrochemical system, in this case, would not only communicate electrical energy to the external conducting system, but it would also simultaneously communicate heat to some external body at a lower temperature. The current flowing through the cell would also cause electrochemical action at both electrolytic junctions. But, although the electrochemical system has given up electrical energy and has, in communicating that energy, undergone electrochemical action at both junctions, it will be found that the chemical state and condition of the system is unchanged, and that the system has lost no energy except heat, due to the reduction of its temperature.

is accounted for as necessarily due to thermoelectric action. Hence, the chemical energy which disappears at this junction could neither have been communicated to another system nor transmitted to another part of the same system in any known form, except that of electrical energy. We must conclude, therefore, that this chemical energy is added as electrical energy to that of the electric current simultaneously crossing the junction. This could occur only by the development of a definite electromotive force at the junction tending to maintain the current. This electromotive force must be directly proportional to the chemical energy lost per unit of time. In other words, the electromotive force, multiplied by the current, must equal the chemical energy simultaneously lost. The electromotive force in this particular case is 1·21 volts, and is accounted for elsewhere in the circuit.

The electrochemical reaction at this terminal of the cell, therefore, is entirely electrogenic. It adds an electromotive force of 1·21 volts to that of the circuit, but neither evolves nor absorbs heat, though there may be and generally is incidentally at this point a simultaneous change of *electrical energy into heat or of heat into electrical energy by thermoelectric action.*

This chemical electromotive force of 1·21 volts cannot be directly measured, because electrochemical action cannot occur at a single terminal only of an electrolyte, and an electric circuit containing only one terminal of an electrolyte is as impossible as a dynamo with only one brush. But when the chemical energy of the reaction is known in the form of heat or in any other form, this electromotive force is determined by calculation on the assumption that energy can be neither created nor destroyed; because this electromotive force, multiplied by the strength of the current at any time flowing, is equal to the power, which expresses the rate at which chemical energy is disappearing by the electrochemical dissolving of the copper. It is to be understood that we are referring to the electrochemical electromotive force only, and not to thermoelectric or other incidental simultaneous transformations.

In passing out of the electrolyte to the electrode, C, the current causes an equal quantity of copper to pass out of the solution by electrochemical action and be deposited on that electrode in the metallic state. The copper, in crossing the junction between the electrolyte and the plate, C, that is, in passing from the state of combination as copper sulphate into the free state as metallic copper, acquires energy of chemical separation, which could be supplied only by the energy of the electric current. Before crossing this junction the copper has not this energy of separation, but after crossing the junction it has the energy of chemical separation. We determine by the same method, therefore, that at this junction an electromotive force of 1·21 volts is absorbed from the electromotive force of the circuit, the action being entirely electrothanic.

The electromotive force absorbed by electrothanic action at C in this particular cell is, therefore, exactly equal to the electromotive force produced by electrogenic action at C'. As these two electromotive forces are equal and opposed to each other, a galvanometer connected to the electrodes will show no difference of potential due to electrochemical action, but will show every difference of potential that may exist due to other causes. Such differences of potential are always present, however, when a current is flowing, that is, when the cell is in action. The electromotive force of this particular cell, as found by a voltmeter connected to its terminals, is, therefore, always a measure, not of the electrochemical electromotive force, but of the sum of all electromotive forces *due to electric inversions other than the electrochemical*, which are taking place in the cell. When no current is passing, there can be no such electric inversions and no electromotive force.

If it were possible to connect one terminal of a galvanometer to the electrolyte at any point between C and C', without introducing an electrode, so that a current due to the electromotive force of one terminal only, of the electrolyte, could flow through the galvanometer, we could then measure directly the electromotive force of a single terminal of the electrolyte. But no method of doing this has

yet been found. The best we have yet been able to do is to measure the algebraic sum of all electromotive forces between two terminals of an electrolyte. The introduction of a third, or so-called "normal" electrode, does not help us in the least, as the electromotive force at the "normal" electrode is always added to that we are measuring. This is evident from the fact that an electric current cannot cross the junction of an electrode and an electrolyte without electrochemical action, and the fact that there is no known chemical action that does not either evolve or absorb energy.

It is evident that the reaction which takes place at the terminal, C', could not occur alone, because we could not add copper to copper sulphate and produce copper sulphate. In other words, $Cu + CuSO_4 = CuSO_4$ is not an equation, either mathematically or chemically, and cannot represent a chemical reaction. Similarly, the reaction at the terminal, C, represented by $CuSO_4 = Cu + CuSO_4$, would, of itself, be impossible. We cannot remove copper from copper sulphate and leave copper sulphate. But by adding these two inequalities together in the proper order in which they occur, we obtain $Cu + 2CuSO_4 = 2CuSO_4 + Cu$, which is an equation representing the sum of the electrochemical reactions at both terminals, that is, the electrochemical action of the system. This equation tells us also that the quantities of copper and copper sulphate and the chemical energy of the system are the same in the initial and final states, though some particles of matter have changed position within the system, and the mechanical energy may not be the same in the two states. Some particles of copper have been transferred from C' and an equal number transferred to C, and the $CuSO_4$ is stronger at C' than at C. Some heat has also been generated within the cell, but the energy necessary for these changes has been received from an external source, namely, the external source of electrical energy included in the circuit.

In all electrochemical reactions both the mechanism and the *modus operandi* are the same as in the electrolytic cell just described. Electrochemical cells may differ in details of

construction, in the nature of the materials used, and in the quantities of electrogenic and electrothanic action, but they never depart from this method of operation (substitution), and no electrochemical reaction is known between two chemical elements without the agency of an intervening electrolyte. Even the most highly electro-positive elements, such as lithium, potassium, sodium or zinc, when brought in contact with the most powerful oxidizing elements, such as free bromine or chlorine, produce heat, but no electrical energy.

If, in the agenic cell shown in *Fig. 4*, we insert a vertical wall or partition of porous clay, so as to divide the cell into two compartments, each containing an electrode and a portion of the adjacent electrolyte, we do not interrupt the con-

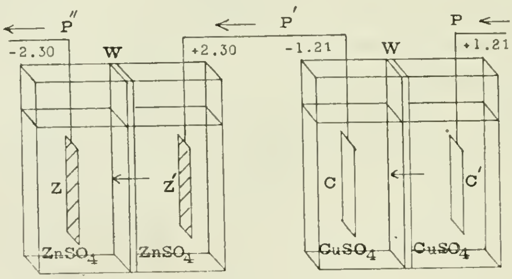

FIG. 5.

tinuity of the electrolyte and do not, therefore, interfere with the electrochemical action of the cell, except by slightly increasing its resistance. We do, however, by such a partition prevent any rapid mechanical intermixture of the two portions of the electrolyte, which are in contact with the two electrodes.

Fig. 5 shows two such agenic cells connected in series, one having copper electrodes, C and C', and an electrolyte containing copper sulphate; the other having zinc electrodes, Z and Z', and an electrolyte containing zinc sulphate, each cell being divided into two compartments by a porous partition, W. As both of these cells are agenic, there is no difference of potential between any of the points P, P' and P'', either on open or closed circuit, if the

circuit includes no other source of electrical energy, the two equal and opposite electromotive forces in each cell producing a condition of perfect equilibrium. If the circuit is rendered active by including an external source of electrical energy, there will be, when the circuit is closed, a difference of potential between any two of the points, P, P' and P'', due to the Joule effect and to thermoelectric inversions, but none due to electrochemical change, as the algebraic sum of the electrogenic and electrothanic actions between any pair of these terminals is zero.

Let us now suppose an electric current to be sent through this series in the direction indicated by the arrow. As already explained, the dissolving of metallic copper from the electrode, C', adds an electromotive force of 1·21

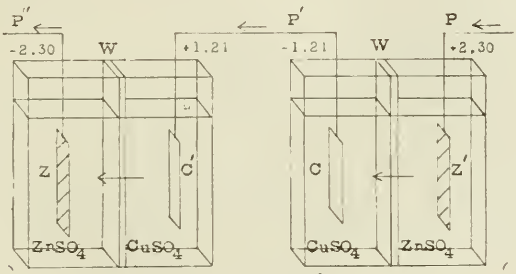

FIG. 6.

volts to that of the circuit, and the deposition of metallic copper at C absorbs an electromotive force of 1·21 volts from that of the circuit. For the same reasons the dissolving of metallic zinc from the electrode, Z', adds to the circuit at that point an electromotive force of 2·30 volts, and the deposition of metallic zinc at the electrode, Z, absorbs 2·30 volts from the circuit. The algebraic sum of these electromotive forces is zero, regardless of the direction of the current.

But it is possible, without altering any of these electrochemical reactions in any way, to interchange the contents of any two compartments or semi-cells. We may, for example, interchange the C' and Z' compartments, giving us the arrangement shown in *Fig. 6*. The algebraic sum

of the four electromotive forces of the two electrochemical systems is still zero, that is, there is no chemical electromotive force between P and P''. But between the points P and P' the sum of the electromotive forces is $2{\cdot}30 - 1{\cdot}21 = 1{\cdot}06$ volts, tending to produce a current in the direction indicated by the arrow; and between the points P' and P'' the sum is also $2{\cdot}30 - 1{\cdot}21 = 1{\cdot}09$ volts, tending to produce a current opposed to the arrow. In other words, the two agenic cells have, by the interchange of compartments, been converted into two cells having opposed and equal electromotive forces. With a current now flowing in either direction, one cell is electrothanic and the other is electrogenic. The sum of their electromotive forces is still zero, and the slightest external electromotive force will send a current through the circuit, causing a transfer of chemical energy from one cell to the other, as well as from one electrode of each cell to the other electrode.

These electrochemical cells are now not only capable of supplying electrical energy at the expense of their chemical energy, by producing a current in a given direction, but are also capable of absorbing electrical energy from a current flowing in the opposite direction and of storing it in the form of chemical energy; that is, they are accumulators as well as galvanic batteries. This cell is also the well-known Daniell cell.

Reversibility of Electrochemical Action.—As an electric current cannot pass into or out of an electrolyte (or chain of electrolytes) without either electrogenic or electrothanic action, every electrochemical cell having dissimilar electrodes is, theoretically, an accumulator when the current passes in one direction and a galvanic battery when it passes in the opposite direction. But in most electrochemical cells the chemical energy accumulated by electrothanic action is not available again for electrogenic action, because the products of electrothanasis pass out of the sphere of action, either by undergoing other chemical changes or by being transported out of the circuit. For the same reasons the chemical energy expended in a primary battery by electrogenic action cannot generally be restored by electrothanic action.

We ought, therefore, to make a distinction between accumulators and storage batteries, as all accumulators are not necessarily storage batteries. That is, electrochemical cells are not all reversible in practice, though they are in theory.

A chemical element or compound, which, in undergoing electrochemical action, is electrogenic and loses chemical energy, may be conveniently called an *electrogen*, and one which is electrothanic, absorbing electrical energy, an *electrothan.*

We have already seen that the same substance may be an electrogen in one cell and an electrothan in another, and that this may be true in the same cell through a reversal of the current.

When zinc, copper or any other metal is separated electrochemically from a compound whose formation heat is positive, the action is always electrothanic and the substance is an electrothan. When these substances combine again electrochemically, the action is always electrogenic and the combining substances are electrogens. The reverse is always true when the formation heat of the compound is negative. The formation heats of all known compounds of the following elements and some others are positive:

Potassium,	Arsenic,
Sodium,	Mercury,
Lithium,	Manganese,
Aluminium,	Zinc,
Barium,	Cadmium,
Strontium,	Iron,
Calcium,	Thallium,
Magnesium,	Copper,
Tin,	Silver,
Lead,	Cobalt,
Sulphur,	Nickel,
Selenium,	Antimony,
Tellurium,	Bismuth,

Chromium.

Hence, these substances, in passing from the free or metallic state into combination of any kind by electrochemical action, are always electrogens and increase the electromo-

tive force of the current flowing from them into the electrolyte. In passing from combination into the free or metallic state by electrochemical action these substances always act as electrothans, opposing a counter-electromotive force to that of the current, which deposits them from an electrolyte.

There are a few compounds of a few elements whose formation heats are negative. They are chiefly compounds of the following elements with one another:

Gold,	Hydrogen,
Bromine,	Nitrogen,
Iodine,	Carbon,
Chlorine,	Oxygen.

These elements, therefore, in passing from the free state into certain particular combinations, act as electrothans, and, in passing from these combinations into the free state, act as electrogens. This is not true, however, of all compounds of these elements.

Electrogenic Power.—The electrogenic power of a compound may be defined as the intensity of the electrical energy evolved by the electrochemical formation of the compound. It is proportional to and measured by the formation heat of the same compound, formed thermochemically. Electrothanic power is merely negative electrogenic power. Or, it may be defined as the intensity of the electrical energy absorbed by the electrochemical formation of the compound.

In the following table of electrogenic powers the chemical symbols, the formation heats expressed in calories, and the corresponding electrochemical electromotive forces or electrogenic powers, expressed in volts, of some of the salts of the more common metals are given. The table might have been greatly extended by adding the iodides and other salts of the metals, but these were thought to be sufficient for the purpose of illustration.

TABLE OF ELECTROGENIC POWERS.

Chlorides.	Calories.	Volts.	Bromides.	Calories.	Volts.	Oxides.	Calories.	Volts.	Sulphates.	Calories.	Volts.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
$LiCl$	102300	4·40	$LiBr$	91500	3·94	Li_2O	83600	3·59	Li_2SO_4	99250	4·27
KCl	101200	4·35	KBr	90400	3·89	K_2O	82600	3·55	K_2SO_4	98800	4·25
$SrCl_2$	97925	4·21	$SrBr_2$	87100	3·75	SrO	79200	3·40	$SrSO_4$	94550	4·07
$NaCl$	96600	4·15	$NaBr$	85800	3·69	Na_2O	77950	3·35	Na_2SO_4	93700	4·03
$CaCl_2$	93700	4·03	$CaBr_2$	82900	3·57	CaO	74800	3·22	$CaSO_4$	90350	3·88
$MgCl_2$	93550	4·02	$MgBr_2$	82300	3·55	MgO	74400	3·20	$MgSO_4$	90000	3·87
Al_2Cl_6	79370	3·41	Al_2Br_6	69100	2·98	Al_2O_3	65500	2·82	$Al_2(SO_4)_3$	76070	3·27
$MnCl_2$	64300	2·77	$MnBr_2$	53500	2·30	MnO	47550	2·02	$MnSO_4$	61050	2·63
$ZnCl_2$	56500	2·43	$ZnBr_2$	45700	1·97	ZnO	41750	1·80	$ZnSO_4$	53450	2·30
$FeCl_2$	50050	2·15	$FeBr_2$	39250	1·69	FeO	34450	1·48	$FeSO_4$	46900	2·02
$CdCl_2$	48200	2·07	$CdBr_2$	38050	1·64	CdO	33150	1·43	$CdSO_4$	45250	1·95
$CoCl_2$	47500	2·04	$CoBr_2$	36700	1·58	CoO	32050	1·38	$CoSO_4$	43900	1·89
$NiCl_2$	46950	2·02	$NiBr_2$	36150	1·56	NiO	30750	1·32	$NiSO_4$	43800	1·89
Fe_2Cl_6	42620	1·83	Fe_2Br_6	31818	1·37	Fe_2O_3	32200	1·39	$Fe_2(SO_4)_3$	37870	1·63
$SnCl_2$	40650	1·75	$SnBr_2$	29950	1·29	SnO	35350	1·52	—	—	—
HCl	39400	1·69	HBr	28600	1·23	H_2O	34500	1·48	H_2SO_4	34500	1·48
$SnCl_4$	39575	1·70	$SnBr_4$	28650	1·23	SnO_2	35350	1·52	—	—	—
$TlCl$	38400	1·65	$TlBr$	41400	1·78	Tl_2O	19850	0·85	Tl_2SO_4	34500	1·48
$PbCl_2$	38950	1·68	$PbBr_2$	28150	1·21	PbO	25400	1·09	$PbSO_4$	37300	1·61
$AgCl$	29000	1·25	$AgBr$	23400	1·01	Ag_2O	3500	0·15	Ag_2SO_4	10750	0·47
$CuCl_2$	31250	1·34	$CuBr_2$	20450	0·86	CuO	18850	0·81	$CuSO_4$	28200	1·21
$HgCl_2$	25150	1·08	$HgBr_2$	18600	0·80	HgO	10750	0·46	$HgSO_4$	1200	0·52
$AuCl_3$	9100	0·39	$AuBr_3$	1870	0·08	Au_2O_3	— 1900	— ·08	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	Cl_2O_5	— 2535	— ·11	—	—	—
—	—	—	—	—	—	Cl_2O	— 2850	— ·12	—	—	—

Columns I, IV, VII and X give the chemical symbols of the chlorides, bromides, oxides and sulphates respectively. Columns II, V, VIII and XI give in gram-calories the formation heat or chemical energy of one univalent electrochemical equivalent, and columns III, VI, IX and XII, the electrogenic powers corresponding to this energy.

The numbers in the energy columns represent the chemical energy of the quantity of each substance, which is

electrochemically equivalent to 1 gram of hydrogen, that is, the energy evolved or absorbed in an electrochemical reaction during the passage of an electric current, which simultaneously liberates 1 gram of hydrogen in a voltameter. These numbers express also in a certain unit the electromotive force added to or absorbed from the circuit at the terminal of the cell, in which the substance takes part in the electrochemical action. Multiplying the numbers in columns II, V, VIII and XI by the constant, ·000043, we obtain, in columns III, VI, IX and XII, these electromotive forces in volts. This electrogenic power, or electrical intensity, represents also the degree of electro-positive character of the metals in the particular compounds given. The constant, ·000043, is obtained by dividing 4·151, the number of watt-seconds equivalent to a gram-calorie, by 96,540 (Ostwald), the number of coulombs required to liberate one univalent gram-electrochemical equivalent of any substance.

To obtain the exact electrogenic power of a compound formed from gases that undergo condensation, we must subtract from the formation heat the energy required to expand the gases again to atmospheric pressure. For example, to expand the oxygen and hydrogen, that forms a gram-molecule of H_2O, would require about 408 gram-calories, equivalent to an electrogenic power of 0·0175 volt. The exact electrogenic power of H_2O is, therefore, $1·484 - 0·0175 = 1·466$ volts.

The chemical energy of a compound, and, consequently, its electrogenic power, is not a quantity inherent in one of the components, but it depends also upon the other substance with which it combines. That is, the energy of a chemical reaction is not primarily inherent in any one of the reacting members, but belongs to the system as a whole, as a result of the primal separation of the several reagents and of the work or energy expended in producing such separation.

Although it is evident from this table that the energy of a combination does not depend on either constituent alone, nevertheless, the simple numerical relations between chlor-

ides and bromides indicate that this energy may be the sum of two or more constants inherent in the several elements.

Galvanic Batteries.—From a table of electrogenic powers, such as the above, we may easily construct a great variety of Daniell cells, or galvanic batteries, of predetermined electrochemical electromotive force by substituting any metal in the list and its chloride, bromide, oxide or sulphate for the copper and copper sulphate in one of the cells shown in *Fig. 6*, or by substituting any metal in the list and one of its salts for the zinc and zinc sulphate, or by replacing both copper and zinc by two of the metals in the list, each in contact with one of its salts. For example, metallic lithium and lithium chloride in one compartment of the cell, with gold and auric chloride in the other, would give an electromotive force of $4{\cdot}40 - 0{\cdot}08 = 4{\cdot}32$ volts. In such a cell we may always use, as a substitute for an electrothanic metal (cathode), without altering the electromotive force, any conductor not electrochemically affected by the electrolyte; because such a conductor is soon plated electrolytically with a deposit of the electrothanic metal. For example, in the cell consisting of lithium and gold with their chlorides we may use a carbon cathode instead of the gold cathode, because on the passage of any current (in the electrogenic direction) gold is deposited on the carbon and it acts exactly as a plate of solid gold. In the copper-zinc cell we may for the same reason use carbon instead of copper without altering the electromotive force. In fact, the electromotive force does not depend in the least on the nature of the metal that passes out of solution, but entirely upon the chemical energy of the reaction, through which it is deposited. Nor does it depend on the nature of the electrodes, but solely on the energy of the reactions occurring at their surfaces.

Limits of Electrogenic Power.—About 4·5 volts is the upper limit of electrochemical electromotive force theoretically obtainable in any single electrochemical system by any combination of known substances, except possibly compounds of caesium, whose chemical energies have not been determined. In addition to the electromotive force thus prede-

termined, there are always thermoelectric transformations and Joule effects taking place in various parts of the system, whenever a current passes. But these are incidental and only affect the final result by being superimposed upon the electrochemical changes.

It may, nevertheless, and sometimes does, happen that these incidental transformations overbalance and entirely mask the electrochemical changes. For example, in the celebrated "carbon consuming cell" of Dr. Jacques (originally invented by Archereau), the electrothanic exceeds the electrogenic action by about 0·33 volt. As an electrochemical system, therefore, the Jacques cell is electrothanic. The thermo-electromotive force of this cell is opposed to and exceeds the sum of the electrochemical electromotive forces by about 1 volt, making it resemble a galvanic cell. In action it gives a thermoelectric current, which by an electrothanic reaction causes chemical energy to accumulate, oxidizing carbon and reducing iron.

This peculiar coincidence, that the thermoelectric action happens to be in the direction to cause oxidation of the carbon, led not only Dr. Jacques, but other eminent physicists, to believe that the energy of the cell was of galvanic, that is, electrogenic origin. An examination of the thermochemical data of this cell, however, which has been given elsewhere,* shows that such a conclusion is untenable.

The question arises, if electrochemical action is always of the same nature as that described above, what is the difference between electrolytic and galvanic action, since both are electrochemical? There is no difference whatever, except in the relative quantities of electrogenic and electrothanic action. In certain cells the electrogenic action exceeds the electrothanic, and in some particular cases there is no electrothanic action, the action being electrogenic at both terminals of the electrolyte. Such cells, in which the electrogenic action predominates, necessarily evolve electrical energy and we call them galvanic batteries. In other cells both reactions may be electrothanic, or the electro-

* *Electrical World*, January 2, 1897.

thanic may exceed the electrogenic action. These cells necessarily absorb electrical energy and acquire chemical energy when in action. They may be distinguished by calling them electrothanic cells. When the electrothanic equals the electrogenic action and the chemical energy is the same in the initial and final states, the cell may be called *agenic*, because it does not generate either chemical or electrical energy. But whether an electrochemical cell is electrogenic, electrothanic or agenic, it is always electrolytic, that is, it operates always by the electrolysis or decomposition of an electrolyte.

Calculation of Electromotive Force.—Whenever an electric current passes through an electrochemical cell there is always a conversion of electrical energy into heat, due to the electrical resistance of the materials composing the cell (Joule effect). This necessitates either a change of temperature or the communication of heat. If the cell is agenic, this could take place only by thermoelectric inversion, which would add to the electrogenic power a thermoelectromotive force proportional to the absolute temperature and the temperature coëfficient.

The calculation of the electromotive force of an electrochemical system in action can, therefore, be made only when its thermochemical constants, its resistance, and its thermoelectric, or temperature coëfficient are known. It is evident, however, that the term for temperature is not to be applied in calculating the electrogenic power of a system at the temperature at which its thermochemical constants have been determined.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held January 26, 1901.

OIL OF WALNUTS (JUGLANS NIGRA, L.).

By Lyman F. Kebler, Member of the Institute.

Frequent and repeated efforts were made to secure a pure oil of walnuts, with the invariable result that the dealers were either unable to supply it, or oils like the following were sent:

No. 1. *Walnut Oil, White.*—This article was colorless, of a sweetish taste, with a peppermint-like flavor and soluble in water and 92 per cent. and 50 per cent. alcohol. Farther investigation showed it to be diluted glycerin, flavored with a menthol-like body.

No. 2. *Walnut Oil, Conc.*—The word concentrated immediately cast a halo of suspicion about this oil, and on submitting it to a fractional distillation about 80 per cent. came over between 78° and 85° C., which was chiefly ethyl alcohol. Then the thermometer rose rapidly to 205° C., which is the boiling point of nitrobenzene (oil of mirbane) and the odor confirmed the boiling point. A small amount of non-volatile matter was left.

When it is remembered that oil of walnuts is chiefly used by artists for paints, because it dries into a varnish which is less liable to crack than linseed oil varnish, the enormity of such adulterations becomes self-evident.

Having been unable to secure an oil of good quality, walnut kernels were secured, ground, and the oil expressed by means of a hydraulic press. In this way 25 per cent. of oil was obtained, while the kernels actually contained 66 per cent. of oil. It was thus deemed of interest to investigate the oil, inasmuch as no such examination seems to have been made.

The oil generally used is that obtained from *Juglans regia*, L., a tree indigenous to Persia and cultivated in Europe and America. The kernels of this nut contain from

30 per cent. to 40 per cent. of "virgin" oil. The fresh cold drawn oil,* is limpid, nearly colorless or pale greenish-yellow and of agreeable taste and odor. Has a specific gravity of 0·925 to 0·9265 at 15° C., saponification number 186–197, iodine value 142 to 151·7, fusing point of fatty acids 16° to 20° C., dries well and is said to be brought into this country from France and Switzerland in 110-gallon tuns.

Hickory nut oil resembles the above walnut oil very much and is known as "American Nut Oil."

Wm. T. Brannt (1896, "A Practical Treatise on Vegetable Fats and Oils," Vol. II, 37) says "oil of black walnuts is sometimes expressed, but is of little value." On examining the cold pressed black walnut oil, the following physical and chemical constants were obtained: It is limpid, of a straw yellow color, possesses a pleasant, agreeable walnut-like odor and taste, becomes turbid at 12° C., has a specific gravity of 0·9215 at 15° C., saponification number 190·1–191·5, acid number 8·6–9, ether number 181·5–182·5, Hehner's number 92·77, Reichart-Missel value 15 cubic centimeters, iodine value 141·4–142·7, melting point of fatty acids 0° C.

The drying qualities are excellent, equal, if not superior in this respect, to linseed oil, leaving a tenacious, flexible, transparent film. An artist on using it pronounced it a very satisfactory article for fine painting.

BOOK NOTICES.

Engine Tests, embracing the results of over one hundred feed-water tests and other investigations on various kinds of steam engines, conducted by the author. By Geo. H. Barnes, S.B., M. Soc. Mech. Eng's, etc. (8vo, pp. 339.) New York: D. Van Nostrand Co. 1900. (Price, $4.00.)

As an advisory contribution for the use of engineers engaged in planning and estimating on industrial steam plants, the data presented in this work, based as they are on the results obtained from actual tests, should relieve them from much embarrassment in reaching reliable conclusions. W.

* "Chemical Analysis of Oils, Fats, Waxes, etc.," by J. Lewkowitsch, 1898, p. 350.

Dynamo-Electric Machinery; its construction, design and operation. Direct Current Machines. By Samuel Sheldon, A.M., Ph.D., assisted by Hobart Mason, B.S. (8vo, pp. 281.) Published by D. Van Nostrand Co., New York. 1900. (Price, $2.50.)

This work has been prepared as a text-book for the courses in electrical engineering given in the technical schools, following especially the lines of the lectures given in the Polytechnic Institute of Brooklyn. It wlll be found equally useful to the general reader. W.

Chemisch-Calorische Untersuchungen über Generatoren und Martiniöfen. Von Hans v. Jüptner und Friederich Toldt. 2te Auflage. Leipzig: Arthur Felix. 1900. 8vo, pp. 96. (Price, R.M. 3.20.)

This work gives the results of an experimental study of the heat effects capable of realization in the improved furnaces of Siemens and Martin. They will be found to be of special value by metallurgical engineers whose professional work embraces the use of furnaces of this type. W.

Modern Electric Railway Motors. By George T. Hanchett, S.B., M. Inst. Elec. Engs. (8vo, pp. 200–iv.) New York: Street Railway Publishing Company. 1900.

The purpose of this work is to describe and explain the operation of the present railway electric motor. The state of the art considered in the work is so unstable that the author finds it necessary to apologize to his readers for the fact that "even during the process of preparing this short work for the press, it has been necessary to make substantial changes in the text to bring it down to date." The data presented in the work have been revised by the engineering forces of the several manufacturers whose products are described, and the work is a satisfactory exposition of the present practice of constructing and operating the railway electric motor. W.

Die Berechnung der Zentrifugalregulatoren. Von J. Bartl, Professor an der k. k. Hochschule zu Graz. Mit 27 in den Text gedruckten Figuren. Leipzig: Arthur Felix. 1900. Pp. 88, 8vo. (Price, R.M. 3.50.)

The above entitled work is a strictly mathematical treatment of the subject of centrifugal governors, embracing every known form of this type of apparatus. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, April 17, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1901.

President JOHN BIRKINBINE in the chair.

Present, 162 members and visitors.

Additions to membership since last month, 15.

The President made the statement that the business affairs of the Institute growing out of its association with the Philadelphia Museums in conducting

the late National Export Exposition had been finally closed by the payment to the Institute of the sum of $10,000, which represented the profit accruing to the Institute for its coöperation in the work.

The paper of the evening was presented by Mr. Chas. Day, who gave an account of the Taylor-White Tool Steel Process. Mr. Day based his remarks upon the experience made with these tools in the works of the Link-Belt Engineering Co., of Philadelphia. The paper was fully illustrated by specimen tools, chips of steel and cast iron, with records attached of speed of tool, depth of cut, etc., etc. Some discussion followed. This paper, with discussion thereon, is referred for publication, and the subject of the invention was, on motion, referred to the Committee on Science and the Arts.

The Secretary gave an informal talk on the Bermuda Islands, detailing some observations he had made during a recent visit to the Islands. The subject was illustrated with a series of lantern slides.

The Secretary also called attention to the fact that the Horological Society of Philadelphia had deposited in the museum of the Institute a valuable collection of antique horological relics and other miscellaneous articles of interest to the watch- and clockmakers' and kindred trades.

The Secretary called attention to a circular received from the Iron and Steel Institute of Great Britain respecting "The Andrew Carnegie Research Scholarship," providing a fund "to enable students who have passed through a college curriculum, or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry." Candidates, who must be under 35 years of age, may obtain full information from the Secretary of the Institute. There is no restriction as to sex or nationality in the grant of this scholarship.

Mr. C. J. H. Chorman offered a resolution to amend the By-Laws of the Institute by reducing the fee for membership to $5. This was amended by Mr. F. M. Sawyer by a motion to increase the annual dues to $10. Both propositions were referred to the Board of Managers, with the request for an opinion as to their expediency.

Adjourned. WM. H. WAHL, *Secretary.*

SECTIONS.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, February 21, 8 P.M. President Morris E. Leeds in the chair. Present, 22 members and visitors.

The paper of the evening was read by Prof. Joseph W. Richards, of Lehigh University. Subject, "Secondary Reactions in Electrolysis." Discussed by Messrs. Reed, Hering, Spencer and others.

The paper was referred for publication.

Stated Meeting, Thursday, March 22. President Morris E. Leeds in the chair. Present, 30 members and visitors.

Mr. Chas. Wirt, of Philadelphia, presented a paper on "Theatre Dimmers and Stage Lighting." The speaker gave an account of the progress that had

been made in this branch of the electrical art, and described certain improvements which he had made in connection therewith. He demonstrated the perfect control that could be obtained over the fly and border lights, and a new application of a dimmer to the projecting lamps which are used in theatre work. (Referred for publication.)

Messrs. Reed, Pawling, Hering and Meeker discussed the paper of the previous meeting, "Secondary Reaction in Electrolysis."

RICHARD L. BINDER, *Secretary.*

Stated Meeting, held Thursday, April 18, 8 P.M. President Leeds in the chair. There were present 74 members and visitors.

The evening was devoted to a communication from Mr. Wm. J. Hammer, of New York, on "Recent European Electrical Progress." The communication, which was profusely illustrated with lantern slides and experiments, consisted of a series of notes and comments upon important electrical developments in Europe, as observed by the speaker at the Paris Exposition, and in the course of a five months' tour through England and the Continent. The following are some of the prominent subjects remarked upon and illustrated: The Nernst lamp; Poulson's telephonograph; the Barmen-Elberfeld suspended electric railway; three-phase railroad work in various countries; utilization of blast furnace gases in gas engines on the large scale; improvements in steam engines, etc.

The speaker received a cordial vote of thanks for his extremely interesting and valuable paper.

WM. H. WAHL, *Secretary pro tem.*

SECTION OF PHOTOGRAPHY AND MICROSCOPY. — *Stated Meeting*, held Thursday, April 4, 1901. Dr. Henry Leffmann in the chair.

The executive committee, which was requested to consider and report upon the proposal to hold a photographic exhibition, made the following preliminary report :

"*To the Section of Photography and Microscopy.*

"The Executive Committee to which was referred the matter of a proposed photographic exhibition, has deemed it advisable to present a preliminary report, in order to secure some expression of opinion as to the scope and nature of the work. As the meeting of the Section in May will be the last prior to the summer recess, time must not be lost by misdirection. In accordance with the expression of sentiment at the meeting in March, Messrs. Samuel Sartain and Frank V. Chambers were added to the committee, as special members with regard to exhibition matters. The committee has held several meetings and has agreed in a general way upon the plan.

"It is proposed that the exhibition shall be comprehensive, including not only all departments of photography, but photographic apparatus, processes, and all methods of picture making by other than light rays strictly so-called. Among the suggestions presented is the following, viz.: to classify the whole subject into three main groups, as follows : Pictorial—Scientific—Applied.

"Under pictorial photography will be comprised landscape, marine portraiture, figure, still-life, genre, etc.

"Under scientific photography will be included apparatus and methods, both of past and present employment, picture making by other than light-rays, and all photographic work adapted rather to research than practical use.

"Under applied photography will be included all adaptations having practical value, such as record work, reproductions of engineering or other drawing, process work, motion pictures, lantern slides, medical and surgical applications of x-rays, micro-photography, photo-micrography and color photography.

"In accepting pictures for the exhibition, the Committee is disposed to consider the general questions of merit either in the practical or technical field and not make any special standard or mode of treatment the sole rule.

"The Committee has given considerable attention to the time and place. It is thought that space might be obtained with nominal cost, at a locality some distance from the Institute; but it is not overlooked that an exhibition at the Institute, if it could be arranged, would be much more satisfactory and advantageous. A great additional attraction would be an exhibition each evening, for about half an hour, of lantern slides, or other general demonstrations in practical matters, and it does not appear that such demonstrations could be carried out so conveniently anywhere as at the Institute.

"The time of the exhibition, it is thought, should be after the first of January 1902, and its duration about three weeks.

"The Committee has not been favorable to the offering of prizes or medals, but believes that certificates of merit or honorable mention might be, with advantage, awarded on uncompetitive judgment.

"It is thought that while no charge should be made for admission some revenue might be derived from the sale of an attractive program or catalogue.

"April 3, 1901."

The report was accepted and ordered to be filed. It was also ordered that the Executive Committee be instructed to confer with the Board of Managers as to the advisability of holding a comprehensive Photographic Exhibition as contemplated in foregoing report, and on the ways and means for carrying the proposition into execution.

An exhibition of lantern slides followed, which embraced among other subjects a series of views of the recently discovered cavern at Mapleton, Pa., made by Mr. W. N. Jennings, and others relating to the Empire of China.

F. M. SAWYER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, April 10, 8 P.M. Prof. F. L. Garrison in the chair. Present, 42 members and 2 visitors.

The paper of the evening was read by Mr. Richard L. Humphrey, on "The Inspection and Testing of Cements." The communication was an exhaustive historical and technical review of the subject. There was some discussion, chiefly by Mr. Robert W. Lesley and the author.

The meeting passed a vote of thanks to the author, and referred his communication to the Committee on Publications.

G. H. CLAMER, *Secretary.*

SATURDAY NIGHT CLUB OF MICROSCOPISTS.

A reception of the "Saturday Night Club of Microscopists" was held at Franklin Institute Hall on Saturday, December 15, 1900, at 8.45 P.M. There were present, besides the regular Club members, a large number of invited guests. The speaker of the evening was introduced by the President, Dr. Joseph C. Guernsey, with the following remarks: "It is the custom of our Club to occasionally invite outsiders, that they may enjoy with us some of our rich intellectual feasts; and we feel that to-night we are offering an exceptionally entertaining and instructive treat in presenting 'Color Photography.' It has been said to me, 'You are a club of microscopists; therefore, what have you to do with color photography?' I shall refer this question to Mr. F. E. Ives, whose persistent investigations of photography in all its branches, extending twenty years, have culminated in the triumph he is about to exhibit to us. I take sincere pleasure in introducing to you Mr. Frederick E. Ives."

Mr. Ives then proceeded to demonstrate the "kromskop" system of recording and reproducing colors by photography, with special reference to its application in pathology. The importance of color in the diagnosis of many diseased conditions, and the desirability of obtaining and preserving for future reference and study the appearance as to color as well as form in many diseased conditions, having long been felt by the medical world. Both upon the screen and in the kromskops, color photographs of pathological subjects were shown, and also examples of a different character, such as landscapes, portraits and works of art. Mr. Ives gave a concise exposition of the principles of the system, explaining the fact that it bore the same relation to color vision that the moving picture apparatus does to life motion, and the phonograph to sound—each system producing in the first instance, not a reproduction of the thing itself, but a record, which was afterward translated to the eye or ear by means of a special device. A special feature of the demonstration was a description of the methods by which the process, first successful only as a laboratory experiment, has been reduced to such a degree of simplicity and precision that it is coming into general practical use.

The demonstration was followed with great interest by all present, and at the close Mr. Ives was tendered a hearty vote of thanks.

Dr. E R. Snader, on behalf of the Club, moved that a vote of thanks be extended to the Franklin Institute for the use of the hall. It was carried by a unanimous rising vote.

After a short discussion of the subject and questions being answered by Mr. Ives, the Club adjourned on motion.

NATHAN SMILIE, M.D., *Secretary.*

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ELECTRICAL SECTION.

Stated Meeting, held December 20, 1900.

ELECTROCHEMICAL ACTION.

BY C. J. REED, Member of the Institute.

(*Continued from p. 393.*)

POLARIZATION.

The *polarization* of an electrochemical cell may be defined as *electrochemical fatigue.* It is caused by the exhaustion of the reagents at the loci of electrochemical action (terminals of the electrolyte or electrolytic chain) and their consequent replacement by other substances, which produce a different and more electrothanic or less electrogenic reaction.

Reverting again to the typical electrochemical cell, such as that shown in *Fig. 4*, having as electrolytes copper sulphate, and as electrodes sheets of copper, it is evident from the local nature of electrochemical action that, if there is no mechanical movement of the electrodes or the electrolyte,

the very thin layer of reagents at the surface of reaction, having a thickness of only a single layer of molecules, will be exhausted as soon as the current corresponding to the quantity of material in that layer of molecules has passed through the cell. When this condition ensues, electrochemical action must cease, unless other reagents are present to act as substitutes for the exhausted material. If other reagents are present, the electromotive force is altered to correspond to their chemical energy. These reagents in turn become likewise exhausted. This exhaustion in most cells of ordinary dimensions would be produced by a very minute current in an exceedingly short time, and before any visible deflection of a galvanometer needle could be produced, if the components of the system were devoid of motion. Either internal mechanical motion of the electrolyte or its particles with reference to the electrodes, or the continuous shifting of the plane of reaction is, therefore, a necessary condition of continuous electrochemical action, except where the active surfaces are of enormous dimensions.

Fortunately we have an agency capable of producing and maintaining this motion, which is always necessarily present in all electrolytes. This agency is *diffusion* and is due, as is well known, to mutual repulsion of the similar particles of a liquid or gas, in virtue of which such particles tend to become uniformly distributed throughout the volume, to which they have access. Let us suppose that in the electrochemical system represented in *Fig. 4* we have an electrolyte consisting of a uniform mixture of particles of water and copper sulphate in any proportion and two electrodes of metallic copper, electrically connected by a copper wire which completes the circuit. The particles of copper sulphate and also those of the water are in a condition of physical equilibrium and uniform distribution. The system is also in a state of electrical equilibrium. Each electrode tends to dissolve in the electrolyte and produce an electromotive force of 1·21 volts. But these electromotive forces are in opposite directions and there is, consequently, a perfect electrical equilibrium. When an electromotive force

from an external source is established in this circuit, tending to send a current through the cell in either direction, it acts upon this balanced system of electromotive forces in the cell in the same manner as the slightest mechanical force, applied to a perfectly balanced scale beam, which causes one end of the beam to move up and the other end to move down without in any way increasing or diminishing the potential energy of the beam itself. In like manner the external electromotive force, applied to this balanced electrochemical system, causes copper to move into solution from one electrode and an equal quantity to move out of solution upon the other electrode. The dissolving of copper from the electrode C' into solution is accompanied by a loss of chemical energy at that electrode, exactly as the downward movement of one end of a balanced beam is accompanied by a loss of energy of position at that end. The movement of copper out of solution and its deposition in the metallic state upon the other electrode is accompanied by an equal accumulation there of chemical energy, exactly as the upward motion of the opposite end of the balanced beam is accompanied by an accumulation of energy of position in that part of the system. In both cases energy has been transferred through the transfer of matter from one part of the system to another part of the same system. This transfer of matter requires the expenditure of a small quantity of energy from an external source, which is dissipated as heat; but in neither case has the energy of the system itself been altered. The potential energy of the one system is the same in the initial and in all succeeding states. So also the chemical energy of the other system is the same in the initial and in all succeeding states.

It is found in this case that there results from the passage of the current, not only the disappearance of copper from C', but also a disappearance of $CuSO_4$ from the surface of C and an accumulation of $CuSO_4$ at the surface of C'. That is, $CuSO_4$ is apparently transported simultaneously with the copper, but in the opposite direction. At the surface, C', where copper disappears, an equivalent of $CuSO^4$ appears, and at the surface, C, where copper appears, an

equivalent of $CuSO_4$ disappears. It is evident, therefore, that after the current has passed, we have no longer a uniform distribution of $CuSO_4$. It is becoming weaker at C and stronger at C'. When the $CuSO_4$ at C is exhausted to such an extent that there are no longer enough molecules to transmit the entire current, the current can be maintained only by increasing the electromotive force, until it is sufficient to decompose the water. This condition, produced by exhaustion of a reagent and resulting in an increase of the electrothanic power or a decrease of the electrogenic power of an electrochemical system, is "polarization."

This removal of $CuSO_4$ from the space adjacent to the electrode, C, on which the copper is deposited, results in an enormous osmotic pressure and a motion of the particles of copper sulphate towards the exhausted region. When the exhaustion extends only to molecular distances from the terminal surface, the re-distribution is practically instantaneous and is produced at a rate proportional to the osmotic pressure, which is proportional to the difference in concentration of the copper sulphate at any two points.

The process of diffusion and re-distribution begins immediately after the equilibrium is disturbed, and, therefore, with solutions of considerable density and with a moderate current (speed of electrochemical reaction), the re-distribution keeps pace with the progress of exhaustion, so that a continuous current may be obtained through the cell without increasing the electromotive force to the point required to decompose the water present. If, however, the motion of the electrolyte is only that due to diffusion, and if the electrochemical action is rapid, partial exhaustion will finally ensue for a considerable distance from the electrode.

When exhaustion proceeds so far that the osmotic pressure can no longer transport the copper sulphate through the exhausted region as rapidly as it is being removed from the surface of the electrode, the strength of the current must be reduced to correspond with the quantity of copper sulphate supplied per unit of time by diffusion to the surface. Whenever the strength of the current is allowed to

exceed this limit, it is evident that water, the other component of the mixture, must suffer decomposition and hydrogen must be deposited. This cannot occur, however, until the impressed electromotive force has attained a value equal to $1{\cdot}48 - 1{\cdot}21 = 0{\cdot}27$ volt. We see, therefore, that the fatigue of this cell, or exhaustion of the copper sulphate at the cathode, causes the water, a more electrothanic substance, to take its place in the electrochemical reaction and suffer decomposition. In other words, polarization of this cell results in the formation of hydrogen at the cathode.

The dependence of continuous electrochemical action upon diffusion, as here stated, can be experimentally observed only when all other sources of motion are eliminated. In the cell described, this is practically possible only when the cathode is in the form of a flat, horizontal surface suspended at the top of the solution, and the anode a flat horizontal surface at the bottom of the solution. Otherwise, the changes in the density of the solution, produced at the electrodes by the elimination of copper at the cathode and its introduction at the anode, immediately cause convection currents, which bring fresh portions of $CuSO_4$ to the cathode and water to the anode. In all ordinary cases of electrolysis this convection is the principal cause of the transportation of matter to and from the electrodes.

Polarization, or exhaustion, is not limited to the cathode, but may also occur at the anode in a manner exactly similar, if two or more reagents are present at the anode and are equally accessible to the electrochemical circuit.

If several independent electrothans are simultaneously present at an electrode of an active electrochemical cell, and are all equally accessible to the circuit, it is evident that the one absorbing the least electrical energy will be the first to undergo electrochemical action and exhaustion. If this substance is not renewed by circulation, diffusion or otherwise, in sufficient quantity to transmit the total current, the other electrothans present will be successively exhausted in the order of their increasing electrothanic power.

In like manner, when several independent electrogens are

simultaneously present at an electrode of an active electrochemical cell, the one supplying the greatest electrical energy will be the first to undergo electrochemical action and exhaustion, and the other electrogens present will be successively exhausted in the order of their decreasing electrogenic power. Thus, potassium would be used up before zinc, zinc before copper, and copper before mercury, when all of these substances are present and equally accessible at the anode of an electrochemical system, having an electrolyte of dilute sulphuric acid.

Any case of polarization is rationally explainable as due to two causes: (1) exhaustion, and (2) the operation of a general law, which we may call the *law of maximum electrogenesis.* It may be stated as follows:

When two or more independent electrogens in the same electrochemical system are equally accessible in parallel to the electrochemical circuit, they are successively exhausted in their order of maximum electrogenic power; and when two or more independent electrothans in the same system are equally accessible in parallel to the same electrochemical circuit, they are successively exhausted in their order of minimum electrothanic power.

The law may also be stated in the following form:

When several independent electrochemical reactions in the same system are equally accessible in parallel to the same electrochemical circuit, they are successively exhausted in their order of maximum evolution or minimum absorption of electrical energy.

According to this law the evolution of electrical energy in the discharge of a galvanic battery tends to be a maximum and the absorption of electrical energy in the charging of an accumulator tends to be a minimum. It is this law that causes zinc to be dissolved before iron, and iron before copper, when all three are in contact in dilute acids. It also causes lead peroxide to be reduced to the monoxide before the monoxide is reduced to the metallic state. The successful electrolytic separation of metals depends entirely upon intelligent obedience to this law. But perhaps the most important result of this law is that it requires that an electrogenic system (a galvanic battery or a charged accumulator) shall run down or discharge itself automatically,

whenever there is an exit for the electrical energy, that is, whenever the electrochemical circuit is completed by a conductor or series of conductors which does not include a source of counter-electromotive force equal to or greater than the electrogenic power of the system.

It is for this reason that a galvanic battery or charged accumulator never requires an external force or agency to *start it* into action. No electrochemical system, unless it is of itself electrogenic, and capable of starting automatically, can be converted into a source of electrical energy by any process of *starting*. And no electrogenic system requires any starting process to set it into action. The closing of the circuit and the maintenance of other physical conditions necessary for electrochemical action are the only requisites. Every chemical reaction requires, for example, that the materials shall be maintained within a certain range of temperatures. But the process of bringing a system into conditions under which electrochemical action is possible, never renders a system electrogenic which was not previously electrogenic. The mere heating of a system of chemical reagents does not impart to it a power of evolving any chemical energy, except that which it previously possessed. All energy absorbed by a system, and used in raising its temperature, can be evolved again only when the system loses its temperature. It is true that additional heat, besides that required to raise the temperature of a system, may be absorbed by the system and simultaneously converted into electrical energy. Electrical energy developed by such a process, however, evidently does not come from the chemical energy of the system, but from thermoelectric inversion.

Many futile attempts have been made to form an electrogenic or galvanic cell by oxidizing carbon in electrochemical reactions which absorb energy, on the supposition that such an action, when once started by the application of an electric current from an external source, would become a source of electrical energy. The reason for the inevitable failure of such devices is apparent. If there is any possibility of obtaining electrical energy from the oxidation of

carbon in an electrochemical cell, it must, at least, be accomplished by an electrochemical reaction that evolves energy.

As already stated, polarization is not a peculiarity of the cathode. Being a condition produced by exhaustion of material, it may occur as easily at one terminal of the electrolyte as at the other. In most galvanic batteries metallic zinc is the anode and, at the same time, the reagent that undergoes exhaustion; but it is generally present in so great an excess that polarization due to exhaustion of zinc does not occur. As this reagent constitutes the electrode itself, it requires no diffusion or other motion to transport it to the surface of reaction, but is accessible as long as it lasts. If, however, the zinc of an ordinary battery were supported on a framework of cadmium, copper, or lead, the electromotive force of the cell would correspond to the electrogenic power of the zinc until the zinc is exhausted. After that the electromotive force would decrease to that corresponding to the electrogenic power of the metal forming the framework, which would act as a substitute for the zinc. This would be a case of polarization at the anode, exactly similar to that of exhaustion at the cathode, except that the reagents are solid metals instead of solutions. In the polarization of a lead accumulator by discharge, the reagents are in part solid and in part liquid at both electrodes and the exhaustion occurs at the anode and cathode alike.

When zinc containing copper and other electro-negative metals as impurities is used in a galvanic cell, the impurity is left on the surface of the zinc and soon acts as a substitute for the zinc, reducing the electromotive force of the cell to correspond to the electrogenic power of the copper or other impurity. The impurity at the same time generally forms a local electrochemical system with the zinc, causing it to be rapidly dissolved and its energy to be dissipated in heat through the Joule effect of the local circuit.

In consequence of the popular belief that polarization can occur only at the cathode, the reagents used at that terminal have received the name of "depolarizers," because, as we shall see later, while these reagents last, there is no polarization. In all electrochemical systems

these cathode reagents, or depolarizers, are invariably what are chemically known as "oxidizing agents," or, more broadly speaking, *they are chemical compounds, one or more components of which suffer diminution of chemical valence in an electrochemical reaction, or they are chemical elements whose valence becomes electro-negative in an electrochemical reaction.* The anode reagents of an electrochemical system (substances that undergo exhaustion at the anode) are invariably "reducing agents," that is, *substances, whose chemical valence suffers an increase or whose electro-negative valence becomes zero or positive.*

Speed of Electrochemical Action.—The rate at which electrochemical action may proceed without the disturbance due to polarization is evidently proportional to the area of the surface of contact between the electrode and the electrolyte, since the quantity of material available at any time is proportional to the extent of the layer of molecules constituting that surface.

The surface exposed to electrochemical action by metals in the ordinary condition is very small, while that exposed by a metal in a finely divided but coherent mass is comparatively enormous. The fact that very large electric currents may be taken from lead accumulators of small dimensions, with slight polarization, is due to the great surface exposure at both terminals of the electrolyte. Here the surfaces of the finely divided lead and lead peroxide, which are bathed in the electrolyte, may be compared to the surface of the leaves of a tree or of a field of moss. We may say in this case that the entire available mass of active material is spread out in a layer of almost molecular tenuity. Such an electrochemical system could give up all of its available energy in an instant without polarization on closing the circuit, if the system had no resistance to limit the current to a certain maximum, and if a sufficient amount of sulphuric acid to unite with all of the available lead and lead peroxide could be contained at one time within the pores of the spongy solids and in contact with their surfaces. But the solution generally used in accumulators contains only about one molecule of acid to twenty-five of

water, so that not more than one twenty-fifth part of the surface can at any instant be in contact with the acid, and diffusion must act, as in all other electrochemical cells, to bring more acid to the terminal surfaces as it is consumed, and also to bring more acid into the spongy mass from without.

Fig. 7 represents, on a greatly magnified scale, a portion of an electrode of a lead accumulator and its adjacent electrolyte. The dark bands may be supposed to represent either filaments of spongy lead or crystals of lead peroxide,

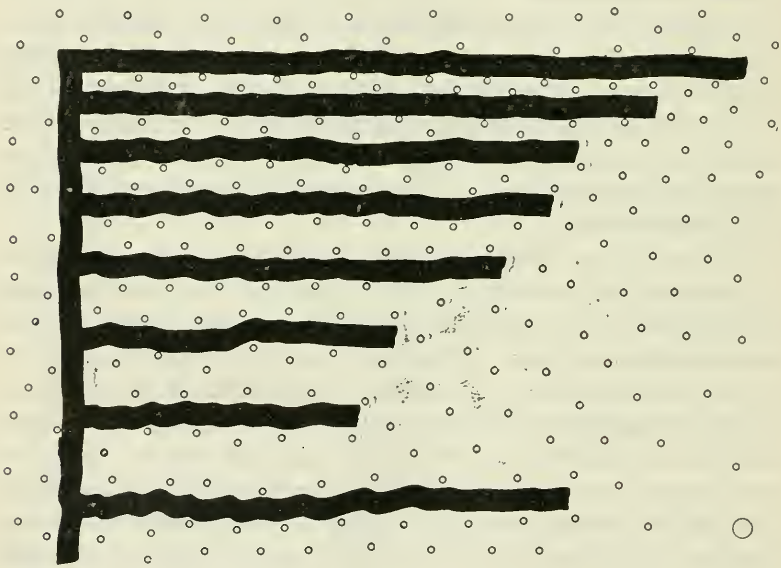

FIG. 7.

and the small circles to represent molecules of H_2SO_4 diffused through the solution. It is apparent that only a small portion of the surface of the electrode is in contact with the molecules of acid. It is also apparent that the spaces between the filaments of lead cannot at one time contain a sufficient number of molecules of acid to cover the entire surface. Before the acid contained in these spaces is consumed, more must pass into the pores of the plate, in order to maintain electrochemical action without polarization.

From the fact that electrochemical action can take place only at the bounding surface of the electrolyte, it follows that all electrodes must be solids or else liquids that do not mix or diffuse through the electrolyte. Otherwise, distinct surfaces of separation would be impossible. Practically we find that all known electrodes are either solids or molten metals or alloys.

An electrode may or may not be one of the electrochemical reagents. The carbon electrode of the Bunsen cell and the copper electrode of the Daniell cell take no part in the electrochemical action, being merely conductors. As conductors they should be mutually interchangeable without affecting the electromotive force of the cell. Carbon may be substituted for the copper of the Daniell cell, but copper cannot be substituted for the carbon of the Bunsen cell, because the copper would be acted upon by the nitric acid.

An interesting series of experiments illustrating this statement is obtained by substituting in the Bunsen cell various metallic electrodes instead of the carbon. A rod of aluminum, for example, substituted for the carbon, gives nearly the same electromotive force as that given by the carbon, though aluminum in sulphuric acid is more highly electro-positive than zinc.* The explanation is very simple. The nitric acid in the Bunsen cell is the electrothanic reagent which undergoes electrochemical action at the carbon electrode, while the electrode itself acts only as a conductor. Therefore, any conductor not chemically acted upon by the nitric acid may be substituted for the carbon without changing the chemical reaction and, hence, without changing the electromotive force. Aluminum happens to be a metal that is not acted upon by nitric acid, and it may, therefore, be used instead of the carbon. By substituting aluminum for both the carbon and the zinc, 1·5 volts may be obtained. We may even replace the carbon by aluminum and the zinc by a more electro-negative metal, such as

* To show that aluminum is electropositive to zinc, both metals should be well amalgamated to remove the influence of impurities, but the aluminum should not be amalgamated when substituted for carbon in the Bunsen battery, as the mercury would be rapidly dissolved.

iron, cadmium, copper, nickel, silver, or mercury, without changing the direction of the electromotive force. It may seem remarkable that we can exchange for the highly electro-negative carbon electrode the highly electro-positive metal, aluminum, and at the same time replace the highly electro-positive zinc electrode by one of a metal so highly electro-negative as copper or silver, without reversing the electromotive force of the cell. But experiment proves and the electrogenic powers of the electrochemical reactions involved require these facts. With this arrangement the following results were obtained experimentally:

Al	HNO_3	H_2SO_4	Zn	1·73 volts.
"	"	"	Cd	1·422 "
"	"	"	Fe	·99 volt
"	"	"	Cu	·66 "
"	"	"	Ni	·64 "
"	"	"	Ag	·40 "
"	"	"	Hg	·305 "
"	"	"	Pb	1·20 volts

These facts corroborate other proofs that the electromotive force of a galvanic cell is not due to the mere "contact" of metals and electrolytes, but to the chemical energy of the electrochemical reaction.

It is evident from the nature of polarization, as defined above and as found practically in all electrochemical cells, whether electrothanic or electrogenic, that the speed of continuous electrochemical action without polarization may generally be materially increased by imparting a rapid mechanical motion to the electrolytes to assist diffusion. We do not mean that the two electrolytes are to be mixed together, but that each electrolyte is to be kept in motion, while the two are separated by a porous wall, except where both electrolytes are of the same material.

Although diffusion is practically instantaneous at molecular distances, it requires considerable time to act at measurable distances, the time being proportional to the square of the distance.

Clogging of Electrodes.—Continuous electrochemical action requires also that the terminals of the electrolyte shall not

be clogged by the products of the reaction. When these products are soluble in the electrolyte, they are rapidly removed by diffusion and mechanical motion, as is the case with the chloride, sulphate, and other salts of zinc. When one of the products of the reaction is a metal or other conducting solid, set free at the electrode, the surface of the electrode is shifted into another plane, the deposited product of the reaction itself becoming the surface of the electrode. This is illustrated in the deposition of copper on the cathode of the copper-zinc cell. But in the lead accumulator the product of the reaction is an insoluble lead sulphate at both terminals, which remains permanently between the electrode and the electrolyte, completely obstructing any further action. In this case the reaction can proceed only until the entire surface of the electrode has undergone chemical change. In such a battery, as already pointed out, the entire mass of available active reagent must be spread out so as to constitute the surface of the electrode.

[*To be concluded.*]

ANTARCTICA: A HISTORY OF ANTARCTIC DISCOVERY.*

By Edwin Swift Balch.

(*Continued from p. 341*)

In 1839 and 1840 Lieutenant Wilkes made a second cruise to the Antarctic, in accordance with his Instructions from the Hon. J. K. Paulding, Secretary of the Navy, which were as follows:†

"Navy Department, August 11th, 1838.

"These objects will, it is presumed, occupy you until the latter end of October; and when attained as far as may be possible, you will proceed to the port of Sydney, where adequate supplies may be obtained. From thence you will

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† "Narrative U. S. E. E.," Vol. I, p. 27.

make a second attempt to penetrate within the Antarctic region, south of Van Diemen's Land, and as far west as longitude 45° E., or to Enderby's Land, making your rendezvous on your return at Kerguelen's Land, or the Isle of Desolation, as it is now usually denominated, and where you will probably arrive by the latter end of March, 1840."

Wilkes' squadron was composed of the sloop of war "Vincennes," 780 tons, under his own command; the sloop of war "Peacock," 650 tons, Commander William L. Hudson; the gun brig "Porpoise," 230 tons, Lieutenant Commander Cadwalader Ringgold; and the pilot boat "Flying Fish," 96 tons, Lieutenant R. F. Pinkney. None of these vessels was suitable for ice work, nor was the expedition properly equipped, for* it "may be borne in mind that our vessels had no planking, extra fastening, or other preparations for these icy regions, beyond those of the vessels of war in our service." The people at Sydney† "inquired whether we had compartments in our ships to prevent us from sinking? How we intended to keep ourselves warm? What kind of antiscorbutic we were going to use? and where were our great ice saws? To all these questions I was obliged to answer, to their great apparent surprise, that we had none, and to agree with them that we were unwise to attempt such service in ordinary cruising vessels; but we had been ordered to go, and that was enough, and go we should. * * * The tender "Flying Fish" excited their astonishment more than the ships, from her smallness and peculiar rig; and, altogether, as a gentleman told me, most of our visitors considered us doomed to be frozen to death. I did not anticipate such a fate, although I confess I felt the chances were much against us, in case we were compelled to winter within the Antarctic. From every calculation we could not stow twelve months' provision, even upon short allowance; our fuel was inadequate to last us more than seven months, and the means of protecting ourselves in the ships for winter quarters, were anything but suffi-

* Wilkes: "Narrative U. S. E. E.," Vol. II, p. 298.
† Wilkes: "Narrative U. S. E. E.," Vol. II, p. 275.

cient. The "Peacock"* was in especially bad condition, for her sheer-streak, to which the channels were bolted and ports hung, was perfectly decayed, fore and aft, and all the stanchions of the upper deck bulwarks were either rotten or in an advanced state of decay. It was, therefore, with unsuitable ships, improperly equipped, that Wilkes started on the cruise which resulted in the great discovery, that in one part of the Antarctic there is a mass of land of sufficient extent to be probably ranked as a continent.

The expedition started from Sydney on December 26, 1839. The tender "Flying Fish" parted company with it on January 1, 1840, and cruised by itself.† On the 21st it made the icy barrier in 65° 20′ south latitude, 159° 36′ east longitude. On the 23d, in 65° 58′ south latitude, 157° 49′ east longitude, they discovered several dark spots, which they made out to be rocks. After this they cruised along the ice barrier until February 5th, when they were in 66° south latitude, 143° east longitude, and were forced to return north on account of sickness.

After parting company with the "Flying Fish," the other ships continued their course south, and on January 7, 1840, were in 54° 20′ south latitude, and 160° 47′ east longitude, not far from Macquarie Island. On the 10th they encountered the first iceberg. On the 11th, at 10.30 P.M., in 60° 11′ south latitude, 164° 36′ east longitude, they were stopped by a compact barrier of ice, enclosing large square icebergs. The water changed to an olive green color. On the 13th, in 65° 8′ south latitude, 163° east longitude, they came up to an icy barrier. "Very lofty ridges of ice,‡ and the loom usual over high land, were visible along the southern horizon, over the barrier. * * * From appearances to the southward, with the numerous *Phocae proboscidae*, I

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*Letters of Mr. Dibble, carpenter, and Captain Hudson: "Narrative U. S. E. E.," Vol. II, p. 449.

† "Narrative U. S. E. E.," Vol. II, pp. 354–359.

‡ Ringgold's Report: "Narrative U. S. E. E.," Vol. II, p. 469.

was strongly impressed with the belief of the close approach of land."*

"On the 16th † the three vessels were in longitude 157° 46′ E., and all within a short distance of each other. * * * On this day (16th of January) appearances believed at the time to be land, were visible from all the vessels, and the comparison of the three observations, when taken in connection with the more positive proofs of its existence afterwards obtained, has left no doubt that the appearance was not deceptive. From this date, therefore, we date the discovery which is claimed for the squadron. * * * On board the 'Peacock,' it appears that Passed Midshipmen Eld and Reynolds both saw the land from the masthead, and reported it to Captain Hudson; he was well satisfied on examination that the appearance was totally distinct from that of ice islands, and a majority of the officers and men were also satisfied that if land could exist, that was it. * * * In Passed Midshipman Eld's journal, he asserts that he had been several times to the masthead during the day, to view the barrier; that it was not only a barrier of ice, but one of terra firma. Passed Midshipman Reynolds and himself, exclaimed with one accord that it was land. Not trusting to the naked eye, they descended for spy-glasses, which confirmed, beyond a doubt, their first impression. The mountains could be distinctly seen, over the field ice and bergs, stretching to the southwest as far as anything could be discerned. Two peaks in particular, were very distinct (which I have named after those two officers), rising in a conical form; and others, the lower parts of which were as distinct, but whose summits were lost in light fleecy clouds. Few clouds were to be seen in any other direction, for the weather was remarkably clear. The sun shone brightly on

* The Balleny Islands are about 1½° of latitude south of the spot where the "Porpoise" was on January 13. It is therefore probable that "the loom usual over high land" was caused by them. I notice that Mr. Borchgrevink, *Geographical Journal*, Vol. XVI, October, 1900, p. 381, appears to be of this opinion, for he says: "I had, however, purposely taken that course in order to satisfy myself respecting the land reported by Captain Wilkes, and which, it seems clear to me, was, in reality, Balleny."

† Wilkes: "Narrative U. S. E. E.," Vol. II, pp. 292, 293.

ridge after ridge, whose sides were partially bare; these connected the eminences I have just spoken of, which must be from one to two thousand feet high. Mr. Eld further states, that on reporting the discovery to Captain Hudson, the latter replied that there was no doubt of it, and that he believed that most of the icebergs then in sight were aground. At this time they were close in with the barrier and could approach no nearer. On this day the 'Peacock' got a cast of the deep-sea lead, with Six's thermometer attached, to the depth of eight hundred and fifty fathoms, only a short distance from the barrier; the temperature of the surface was 31°, and at the depth sounded, 31½°, current one fourth of a mile, north by east."

"On the evening of the 16th,* strong appearances of land again arose, in corroboration of which I insert an extract from my journal, as well as the remarks from the log-book. * * * Extract from Journal. 'At 6 h. 30 m. P.M. I went aloft to take a look, the weather being clear, horizon good and clouds lofty. I heard the noise of a penguin; soon after, one was seen very near the brig, with a large seal to windward. After reaching masthead, I saw over the field of ice, an object, large, dark and rounding, resembling a mountain in the distance. The icebergs all were bright and brilliant, and in great contrast. * * * I watched for an hour to see if the sun in his decline would change the colour of the object by a difference of rays; it remained the same, with a white cloud above, similar to those generally hovering over high lands; at sunset it remained the same. I took the bearing accurately, intending to examine it closely as soon as I got a breeze. I am strongly of the opinion it is an island, surrounded by immense fields of ice now in sight.' * * * Extract from Log. 'At 7 P.M. discovered what was supposed to be an island, bearing south-by-east—a great deal of field-ice in sight. (Signed) J. H. North. * * * 17th, the indications were again noticed, corroborating those of the day preceding.'

* Ringgold's Report: "Narrative U. S. E. E.," Vol. II, pp. 469, 470.

"On the morning of the 19th * we found ourselves in a deep bay, and discovered the 'Peacock' standing to the southwest. Until eight o'clock A.M. we had a moderate breeze. The water was of a darker olive-green, and had a muddy appearance. Land was certainly visible from the 'Vincennes,' both to the south-southeast and southwest, in the former direction most distinctly. Both appeared high. It was between eight and nine in the morning when I was fully satisfied that it was certainly land, and my own opinion was confirmed by that of some of the oldest and most experienced seamen on board. The officer of the morning watch, Lieutenant Alden, sent twice and called my attention to it. We were at this time in longitude 154° 30′ E., latitude 66° 20′ S., the day was fine, and at times quite clear, with ligh winds. After divine service, I still saw the outline of the land, unchanged in form but not so distinct as in the morning. By noon, I found we were sagging on to the barrier; the boats were lowered in consequence, and the ship towed off. The report from aloft was, 'A continued barrier of ice around the bay, and no opening to be seen, having the western point of it bearing to the northward of west of us.' I stood to the westward to pass around it, fully assured that the 'Peacock' would explore all the outline of the bay."

"On Sunday, January 19th,† while standing into a bay of ice, in latitude 66° 31′ S., and longitude 153° 40′ E., we made (what we believed to be) land to the southward and westward. * * * It was seen towering above and beyond some large icebergs, that were from one hundred to one hundred and fifty feet in height. We endeavored to work up for this land, which presented the appearance of an immense mass of snow, apparently forming a vast amphitheatre, with two distinct ridges or elevations throughout its extent. After working until midnight through detached portions of ice, we reached the barrier at the head of the bay, and were compelled to give up any further attempt to

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* Wilkes: "Narrative U. S. E. E," Vol., II, page 295.

† Hudson's Report: "Narrative U. S. E. E.," Vol. II, page 465.

near it (what we believed to be land), and passed out of the bay again, which was some twenty miles in extent, through drift-ice into a more open space for pursuing our course to the southward and westward along the barrier."

"On the 22d, 4 A.M.,* appearances of land again to the southward and eastward, at the time passing an iceberg with dark veins and dusty appearances, exciting confident hopes of soon making positive discoveries."

"On the 23rd † of January we made, beyond the barrier, which was thickly studded with bergs and islands of ice, (what we believed to be,) high land, at least so far as terra firma can be distinguished where everything is covered with snow, and worked into a bay for a nearer and more minute examination. The sea water had been discoloured for some days, but no bottom obtained by soundings; in the bay, however, it changed to a dark dull green, and gave every indication that we were on soundings, and not far from land. * * * The result confirmed the appearances: we obtained bottom in three hundred and twenty fathoms, of slate-coloured mud, and the lead brought up with it a piece of stone, about an inch in length, of nearly the same colour, while the lower part of the lead showed a fresh and deep indentation, as though it had struck on a rock. Dip observations were made on the ice with Robinson's and Lloyd's needles; the former gave 86·10,° the latter 86·23°. While ascertaining the dip, a large king-penguin was captured on the ice, and brought to the ship; to add to our collections, in his stomach were found thirty-two pebbles of various sizes, which appeared to have been very recently obtained, and afforded additional evidence of our immediate proximity to land."

A tremendous storm now arose, in which the "Peacock" was so severely damaged by contact with icebergs, that it was indispensable for her to return north, which was done. It was found that "the ice had chafed the stem to within one inch and a half of the wood-ends of the planking."‡

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* Ringgold's Report: "Narrative U. S. E. E.," Vol. II, p. 470.

† Hudson's Report: "Narrative U. S. E. E.," Vol. II, page 465.

‡ Hudson's Letter: "Narrative U. S. E. E.," Vol. II, page 468.

The "Vincennes" and "Porpoise" continued sailing along the coast. An ice-bound bay was explored on January 23d, and called Disappointment Bay. It was in 67° 4′ 30″ south latitude, and 147° 30′ east longitude. On the 28th there was another terrible gale, in which the ships escaped destruction from contact with icebergs by sheer good luck.

On January 30th, "we approached* within a half mile of the dark, volcanic rocks, which appeared on both sides of us, and saw the land gradually rising beyond the ice to the height of three thousand feet, and entirely covered with snow. It could be distinctly seen extending to the east and west of our position fully sixty miles. I make this bay in longitude 140° 02′ 30″ E., latitude 66° 45′ S., and now that all were convinced of its existence, I gave the land the name of the Antarctic Continent. Some of the officers pointed out the appearance of smoke, as if from a volcano, but I was of the opinion that this was nothing but the snow-drift, caused by the heavy squalls. There was too much wind at this time to tack, I therefore had recourse to luffing the vessel up in the wind, and wore her short round on her heel. At the same time we sounded, and found a hard bottom at the depth of no more than thirty fathoms. I made a rough sketch of this bay, which I have called Piner's Bay, after the signal quarter-master of that name."

At this time there was much sickness on the ship, and Wilkes sent official letters to the officers and surgeons asking for their opinion about what course should be taken. Their answers, dated January 31st, are interesting. "We have been almost surrounded† with drift-ice and ice-islands for the last twenty-three days, and coasting along the barrier of field-ice, which has rendered it impossible to penetrate further south in this vicinity; and, although gratify-

* Wilkes: "Narrative U. S. E. E.," Vol. II, page 316.

† Purser R. R. Waldron, of the "Vincennes": "Narrative U. S. E. E.," Vol. II., page 462. This letter is important, because it proves that on January 31, 1840, the name "Antarctic Continent" had been definitely given, and also because this mention of it is probably the first time it was written officially (unless in the log).

ing it would be to land upon the Antarctic Continent, I am not aware that any advantages to be derived from it would be commensurate for the dangers it would be necessary to incur; and if the discovery of new land in these regions is important, I consider it equally so that every precaution be taken to communicate the same to others." * * * "We would state* that in our opinion, it would be as well to hold on until to-morrow at meridian, in order, should the weather then prove favorable, to attempt making the recently-discovered land at another point" * * * "I am of opinion† with due regard to the report of the medical officers, which you have submitted to our perusal, that it is very desirable to ascertain the extent of the recently-discovered land, by another attempt to the westward." * * * "I think‡ it would be advisable to remain in this vicinity at least two days longer, and if possible, get further information respecting the recently-discovered land."

"The 2d of February§ found us about sixty miles to the westward of Piner's Bay, steering to the southward, and as usual among ice-islands, with the land in sight. The land had the same lofty appearance as before. * * * Our longitude now was 137° 02′ E., latitude 66° 12′ S." * * * "On the 7th|| we had much better weather, and continued all day running along the perpendicular icy barrier, about one hundred and fifty feet in height. Beyond it the outline of the high land could be well distinguished. * * * I place this point, which I have named Cape Carr, after the first lieutenant of the 'Vincennes,' in longitude 131° 40′ E., and latitude 64° 49′ S." "On the 10th * * * running close along the barrier, which continued of the same character, although more broken than yesterday, we saw an ap-

* First Lieutenant Overton Carr; Lieutenants A. Ludlow Case and Joseph A. Underwood; Acting Masters Edward H. deHaven, and Samuel R. Knox, of the "Vincennes: "Narrative U. S. E. E.," Vol. II, page 461.

† Lieutenant James Alden: "Narrative U. S. E. E.," Vol. II, page 462.

‡ Chaplain Jared Elliott: "Narrative U. S. E. E.," Vol. II, p. 463.

§ Wilkes: "Narrative U. S. E. E.," Vol. II, p. 320.

|| Wilkes: "Narrative U. S. E. E.," Vol. II, p. 321.

pearance of land, although indistinctly, to the southward * * * longitude 122° 35′ E., latitude 65° 27′ S." "During the 12th* we had pleasant weather and at 2 A.M. filled away. At 8 A.M. land was reported to the southwest. * * * Land was now distinctly seen, from eighteen to twenty miles distant, bearing from south-southeast to southwest—a lofty mountain range, covered with snow, though showing many ridges and indentations. * * * We had decreased our longitude to 112° 16′ 12″ E., while our latitude was 64° 57′ S. This puts the land in about 65° 20′ S., and its trending nearly east and west."

"I gained the meridian of 105° E.† on the 12th of February, latitude 64° 54′ S.; the weather was at intervals misty, affording little opportunity for observation; many strong indications of land presented themselves. * * * As I advanced westward, the marks of the approach to land were becoming too plain to admit a doubt. The constant and increasing noise of penguins and seals, the dark and discolored aspect of the ocean, with frequent huge masses of black frozen earth identified therewith, strongly impressed me with the belief that a positive result would arise in the event of a possibility to advance a few miles further south. * * * On the afternoon of the 13th, I landed and extracted from an immense mass of black earth identified with the barrier, some hundreds of yards back from the margin, specimens of rock corresponding to those previously obtained." * * *

"13th‡ * * * In the afternoon we had the land ahead, and stood in for it with a light breeze until 6½ P.M. when I judged it to be ten or twelve miles distant. It was very distinct, and extended from west-southwest to south-southeast. We were now in longitude 106° 40′ E., and latitude 65° 57′ S. * * * 14th.§ At daylight we again made sail for the land, beating in for it until 11 A.M. when

* Wilkes: "Narrative U. S. E. E.," Vol. II, page 324

† Ringgold's Report: "Narrative U. S. E. E.," Vol. II, pages 471,472.

‡ Wilkes: "Narrative U. S. E. E.," Vol. II., page 324.

§ Wilkes: "Narrative U. S. E. E.," Vol. II, page 325.

we found any further progress quite impossible. I then judged that it was seven or eight miles distant. The day was remarkably clear, and the land very distinct. By measurement, we made the extent of coast of the Antarctic Continent, which was then in sight, seventy-five miles, and by approximate measurement, three thousand feet high. It was entirely covered with snow. Longitude at noon, 106° 18′ 42″ E., latitude 65° 59′ 40″ S. * * * I determined to land on the largest ice-island that seemed accessible. * * * We found embedded in it, in places, boulders, stones, gravel, sand and mud or clay. The larger specimens were of red sandstone and basalt. No signs of stratification were to be seen in it, but it was in places formed of icy conglomerate (if I may use the expression) composed of large pieces of rocks, as it were frozen together; and the ice was extremely hard and flint-like. The largest boulder embedded in it was about five or six feet in diameter, but being situated under the shelf of the iceberg, we were not able to get at it. Many specimens were obtained and it was amusing to see the eagerness and desire of all hands to possess themselves of a piece of the Antarctic Continent. These pieces were in great demand during the remainder of the cruise. * * * This island had been undoubtedly partly turned over. * * * On the 17th* about 10 A.M. we discovered the barrier extending in a line ahead, and running north and south as far as the eye could reach. Appearances of land† were also seen to the southwest, and its trending seemed to be to the northward. We were thus cut off from any further progress to the westward, and obliged to retrace our steps. * * * We were now in longitude 97° 37′ E., and latitude 64° 01′ S."

The expedition now turned northward and the "Vincennes" proceeded first to Hobart Town, then to Sydney, which it reached on March 11th. Lieutenant Wilkes immediately announced the discovery of a South Polar Continent to the

* Wilkes: "Narrative U. S. E. E.," Vol. II, page 327.

† Termination Land, whose existence is still uncertain. Dr. Fricker ("The Antarctic Regions," page 221) suggests that Wilkes may have seen land by refraction.

Secretary of the Navy in the following letter, dated at Sydney, New South Wales, March 11, 1840:—

"It affords me much gratification to report that we have discovered a large body of land within the Antarctic Circle, which I have named the Antarctic Continent, and refer you to the report of our cruise and accompanying charts, inclosed herewith, for full information relative thereto."*

As far as I know, this is the first definite announcement of a mass of land, probably continental in size, in the Antarctic Region. Five or six explorers *may* have sighted the South Polar Continent prior to 1840, but none of them saw enough land to be able to assert that he had seen anything more than islands. The nearest approach to such a statement was the casual remark of Edmund Fanning about Palmer's Continent. A strong proof that there was no knowledge of an Antarctic Continent, prior to 1840, is furnished by the charts published before that date. No land is charted by Weddell, except south of South America, and on Biscoe's chart there is no land marked east of Enderby Land, up to the lands south of Cape Hoorn. Unless, therefore, some prior claim can be proved, the honor of recognizing the existence of a South Polar Continent belongs to Commodore Wilkes and to the United States Exploring Expedition.

Two days later, the first account of the discovery of a South Polar Continent ever printed, was published in *The Sydney Herald* of March 13, 1840. I have not seen the original of this, but there is a reprint of it in the *Nautical Magazine* for 1840.† The article is as follows:—

"An interesting geographical discovery has been made in the Southern Antarctic Ocean, of a Continent with a coast of about 1,700 miles from east to west, highly useful for seal and whale fishery. The most singular coincidence

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* Captain C. C. Todd, U. S. N., Hydrographer, called my attention to this letter. It was first published in Mr. G. W. Littlehales' "The navy as a motor in geographical and commercial progress;" *Bulletin of the American Geographical Society*, Vol. XXXI, 1899, pages 123–149.

† "*The Nautical Magazine and Naval Chronicle for 1840*," London, Simpkin, Marshall & Co., page 592.

is, that it was discovered by the French and Americans on the same day, January 19, 1840, at a distance of 720 miles from each other.

"Amongst the arrivals to be found in our shipping list of this day, is that of the United States ship 'Vincennes' under the command of Charles Wilkes, Esq. The 'Vincennes' has been absent from this port almost eighty days, most of which time has been spent in southern exploration, and we are happy to have it in our power to announce, on the highest authority, that the researches of the exploring expedition after a southern continent have been completely successful. The land was first seen on the morning of the 19th of January, in latitude 64 deg. 20 min. south, longitude 154 deg. 18 min. east.

"The 'Peacock' (which ship arrived in our harbor on the 22d ult., much disabled from her contact with the ice,) we learn, obtained soundings in a high southern latitude, and established beyond doubt the existence of land in that direction. But the 'Vincennes' more fortunate in escaping injury, completed the discovery, and run down the coast from 154 deg. 18 min. to 97 deg. 47 min. east longitude, about seventeen hundred miles, within a short distance of the land, often so near as to get soundings with a few fathoms of line, during which time she was constantly surrounded with ice-islands and bergs, and experiencing many heavy gales of wind, exposing her constantly to shipwreck. We also understand that she has brought several specimens of rocks and earth procured from the land, some of them weighing upwards of one hundred pounds.

"It is questionable whether this discovery can be of any essential benefit to commerce; but it cannot be otherwise than highly gratifying to Captain Wilkes and the officers engaged with him in this most interesting expedition, to have brought to a successful termination the high trust committed to them by their country, and it is hoped that so noble a commencement in the cause of science and discovery will induce the Government of the United States to follow up by other expeditions that which is now on the point of termination.

"We understand that the 'Vincennes' will sail on Sunday or Monday next, for New Zeeland (*sic*), where the 'Porpoise' and 'Flying Fish' will rejoin her, should they have been equally fortunate with their two consorts in escaping from the ice. The 'Peacock,' will follow as soon as her repairs are completed; whence they will all proceed in furtherance of the objects of the expedition.—*Sydney Herald, 13th March.*"

The cruise of Wilkes will remain among the remarkable voyages of all time. No finer achievement has been accomplished in the annals of the Arctic or of the Antarctic.* With unsuitable, improperly equipped ships, amid icebergs, gales, snow storms and fogs, Wilkes followed an unknown coast-line for over fifteen hundred miles, a distance exceeding in length the Ural Mountain Range. It is the long distance which Wilkes traversed which makes the results of his cruise so important; for he did not merely sight the coast in one or two places, but he hugged it for such a distance as to make sure that the land was continental in dimensions. The expedition noticed appearances of land on January 13th; it sighted land almost surely on January 16th, from 157° 46′ east longitude, and again more positively on January 19th, from 154° 30′ east longitude, 66° 20′ south latitude. The discovery, therefore, was made probably four days earlier than that of D'Urville. On January 30th, the size of the land was sufficiently ascertained to receive the name Antarctic Continent, and this discovery of Wilkes and that of Gerritz are the two most important discoveries yet made in the Antarctic.

It is scarcely probable, however, especially when the constant fogs and snow storms are taken into consideration, that the outline of the coast of Wilkes Land is accurate, sketched in as it was during a single reconnaissance; but that there is the shore of a continent between about 154°

* The able and impartial Sir John Murray, for instance, in "The Renewal of Antarctic Exploration," *Geographical Journal* Vol. III, 1894, pages 1-42, says at page 11: "When we remember that their ships were wholly unprotected for ice, the voyages of D'Urville and Wilkes to the Antarctic Circle south of Australia must be regarded as plucky in the extreme."

and 100° east longitude, can scarcely be doubted by anyone who reads the "Narrative." The vast number of ice islands and tabular icebergs shows that there is some extensive nucleus which retains them in an uninterrupted line on nearly the same degree of latitude, and moreover these enormous bergs are not formed, according to most explorers, in the open sea. Along this extended coast neither any open strait nor any northerly currents were observed, and the absence of both are strong proof of a continental mass of land, rather than of an archipelago of islands.

It is in accordance with tradition, however, that Wilkes should be traduced for having discovered something. Marco Polo's account of the *Ovis Poli* was disbelieved for six hundred years. Columbus was put in chains. Amerigo Vespucci, who, like Wilkes, first recognized the existence of a continent, has not, even yet, had his character restored to him. Baffin's Bay took many shapes during two centuries and was just disappearing altogether when Sir John Ross saved it. Abel Tasman was told that he had not accomplished anything and that better men would be sent. Paul B. du Chaillu, the hunter of the gorilla and the discoverer of the pigmies, was advised by his publishers "to stick to it." Henry M. Stanley learnt that he had been rescued by Dr. Livingstone, who was "in clover," *et cetera.* It is not to be wondered at, therefore, that Wilkes should be disbelieved; but the fact that he has been so much attacked only proves that he did discover something of which the world was ignorant at the time.*

*Some of the officers of the United States Expedition—William M. Walker, Lieut.; Robert E. Johnson, Lieut.; James Alden, Lieut.; John B. Dale, Lieut.; Edwin J. DeHaven, Lieut.; A. S. Baldwin, Lieut.; George T. Sinclair, Lieut.; William Reynolds, Lieut.; Simon F. Blunt, Lieut.; William May, Lieut.; Joseph P. Sanford, Lieut.; George Colvoccoressis, Lieut.; James Blair, Passed Midshipman—felt aggrieved about some of the statements published by Lieutenant Wilkes in his "Narrative." In consequence they prepared a paper: "Memorial of Officers of the Exploring Expedition to the Congress of the United States;" Washington, January, 1847, page 23. All the complaints made by these officers are purely *personal* ones, about matters or charges which they considered reflected on them personally. The only mention at all of the Antarctic cruise is the following (page 12): "'Vol. 2, page 359—Lieutenant Pinckney was enabled to come again on deck, who had scarcely

Impartial geographers in due time recognized the importance of Wilkes' discovery, and in recognition of his work affixed the name of Wilkes Land to the portion of the Antarctic Continent along which he coasted. I do not know who suggested the name of Wilkes Land, nor on what map or atlas it first appeared, but it is found as far back as 1866, in "Stiehler's Atlas," Justus Perthes, Gotha. It is found also in Bartholomew's "The Library Reference Atlas," 1890; in the "Library Atlas of Modern Geography," D. Appleton, New York, 1892; in Justus Perthes' "Taschen Atlas," Gotha, 1893; in Sir John Murray's map, "Geographical Journal, Vol. III, 1894; in Alex. Keith Johnston's "The Royal Atlas," 1894; in "The Century Atlas," 1897; in "The Times Atlas," London, 1895, 1896, 1897, *et cetera*. Hachette's "Atlas de Poche," Paris, 1894, prints "T. de Wilkes," and it is particularly instructive to find the countrymen of Dumont D'Urville using the term. Some geographers still use the term "Antarctic Continent." Colton's "General Atlas," New York, 1888, for instance, does so, and also the Hydrographic Office in Washington. Some map makers, however, use neither name. In Black's "General Atlas of the World," Edinburgh, 1876, there is the complete outline of Wilkes Land, but no American name whatever, and only Adélie, Clarie and Sabrina Land. In the "Encyclopædia Britannica," ninth edition, article "Polar Regions," is a map with the names given by Wilkes and D'Urville, as well as Sabrina Land, but with neither "Antarctic Continent," nor "Wilkes Land."

There is no doubt, however, I think, that in due time, in accordance with the excellent precedent of commemorating the names of explorers, the name already in general use among geographers will prevail, and that on future charts, instead of "Antarctic Continent" there will be placed "Wilkes Land."

[*To be continued.*]

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been able to quit his berth since leaving Maquarie Island, from sickness.'" The following half page explains that this sentence is incorrect, and that the commander of the "Flying Fish" was on duty, with the exception of one or two days, during the whole of his cruise in the Antarctic.

ROTARY TRANSFORMERS:
THEIR HISTORY, THEORY AND CHARACTERISTICS.

By George W. Colles, A.B., M.E.

(*Continued from p. 368.*)

THE INDUCTORIUM.

We return to this class from the point where we left it, on page 222*; but better prepared to consider its capabilities, and from a different standpoint; and we commence by redefining the inductorium—as we shall at present consider it—as a self-contained induction coil or series of coils, one of whose sides is connected to a commutator, adapting it to mediate between alternating or polyphase and continuous currents. By "self-contained" is meant that it is not acted on by external magnetic fields; and it is hence, in general, stationary.

Some pages back (page 362†) the suggestion was referred to that polyphase generators and their corresponding transformers might be made with a very large number of phases, as many, in fact, as the secondary of the transformer has commutator segments. Now, supposing this to be the case, if we provide means for continuing the synchronous rotation of the commutator, there is no longer occasion for an armature to assist the commutation of the current, because each commutator bar, as it comes under the brushes, will assume its maximum potential, which is that of the *D C* circuit, which latter, therefore, is supplied with a constant (or sensibly constant) pressure.

Now, as it is not convenient to carry thirty or forty line-wires from the generating station, we must, to accomplish this transformation, obtain some means of first transforming the polyphase current of two or three phases only into the requisite large number of phases. Now, this is done without the slightest difficulty by means of the original

*March number of this *Journal.*
†May number of this *Journal.*

ring transformer shown in Plate XIV, in the manner already mentioned on page 263.* Dividing the secondary coils into the requisite number of segments and connecting them through slip-rings to the respective segments of the commutator above mentioned, we at once have our inductorium.

This is the fundamental principle upon which are constructed most of the recent machines of this type; and, with a slight addition, most of the frequency changers as well. As we see, our new apparatus is nothing more than a metamorphosed two-coil rotary armature, minus the fields.

This simple form is shown in Plate XXI, *Fig. 1*.[75] Here *R* is the induction ring, double-wound with an open-coil two-phase primary, as in Plate XIV,† *Fig. 1*, and a Gramme-wound secondary, connected up to the stationary commutator *C*, upon which brushes *x y* are synchronously revolved by the auxiliary magnet *A*, delivering continuous current to the slip-ring brushes *p q*. (*Fig. 2* is an alternative form with double auxiliary magnet.)

The old ring form of transformer, when used in this manner, is, however, as we already saw on page 219,‡ when treating of the *D C* inductorium, and again on page 264,§ when speaking of the polyphase transformer, inefficient and unsatisfactory on account of its open magnetic circuit, or free poles at opposite sides of the ring. Now, by juxtaposing another ring with free poles of opposite kind, we complete the magnetic circuit (*Fig. 3*). Or we may place within the ring an iron drum, which effects the same purpose (*Fig. 4*).

In these cases both cores may be wound with primary and secondary circuit and the proper one commuted at the brushes. Or on the other hand we may wind the primary on the exterior ring, and the secondary drum-fashion on the center-piece (*Fig. 5*), or *vice versa* (*Figs. 6* and *7*). In all these cases both cores are fixed, and only the brushes *x y* rotated on their spindle by the bar magnet *A*.

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*April number of this *Journal*.

[75] Zipernowski and Deri's patent, No. 433,758, of August 5, 1890.

†April number of this *Journal*.

‡March number of this *Journal*.

§April number of this *Journal*.

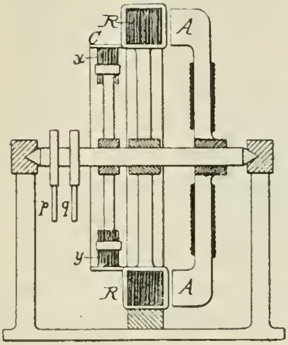


Fig. 1.

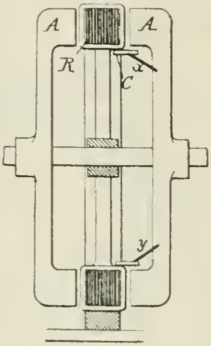


Fig. 2.

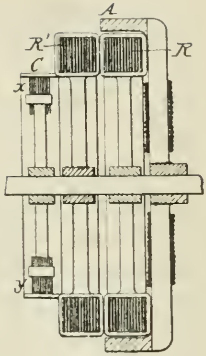


Fig. 3.

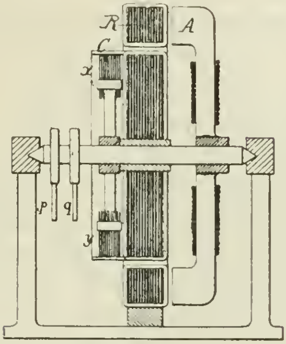


Fig. 4.

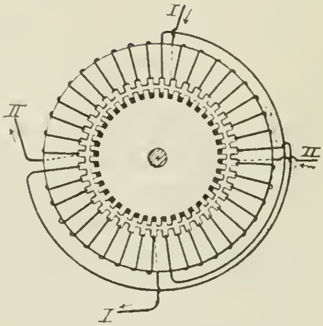


Fig. 5.

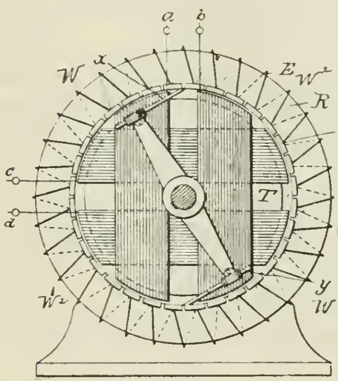


Fig. 6.

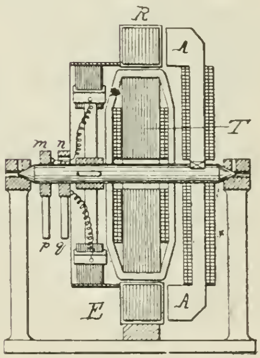


Fig. 7.

PLATE XXI.—Various forms of inductorium, as given by Zipernowski & Déri. 1890.

Now compare these forms with those shown in Plates IV and VI.* We see at once the practical identity of *Fig. 1* with Plate IV, embodying the rotating "magnetic bridge" with its brushes and slip-rings; while the forms of *Figs. 3, 4, 5, 6* and *7* correspond precisely with the forms shown in Plate VI; but with this difference, that one unnecessary commutator, with its brushes and slip-rings, is omitted (see page 263, bottom†). Again, in *Fig. 5*, we see a dynamotor with fixed armature and rotating field; the rotation, however, being not mechanical, but magnetic. We see, then, that these *A C* forms of the inductorium stand in precisely the same relation to the two-coil rotary transformer as the *D C* forms do to the dynamotor.

There are, however, two important distinctions between the two classes which we must not lose sight of; to wit, first, that in the *A C* form the period of rotation is fixed and governed by external conditions; in the other, it may be anything, depending on the lead of the magnet over the brushes, the friction, and minor considerations. Secondly, the primary of the *A C* form is traversed by a true (sinusoidal) alternating current; that of the *D C* form only by a constant current periodically reversed in each successive coil (see page 276‡), thus producing a field which changes intermittently by a series of steps or jumps. The distinction is as essential as that between a dynamotor and a two-coil rotary transformer.

In all these forms, however, there is no completely closed circuit of iron for the magnetic flux; all have an air-gap. Yet there is no necessity of an air-gap in such forms as *Fig. 5*, and the teeth may be advantageously joined, not merely to complete the magnetic circuit, but to brace the internal core against the rotative effect imparted to it by the rotating field in the ring surrounding it. An apparatus of this form is shown in Plate XXII, from a recent patent to Humphrey,[76] which shows a decided advance over

*March number of this *Journal*.

†April number of this *Journal*.

‡April number of this *Journal*.

[76] No. 628,807, of July 11, 1899.

previous forms. We no longer have two separate cores, but a single one composed of a solid core built up of

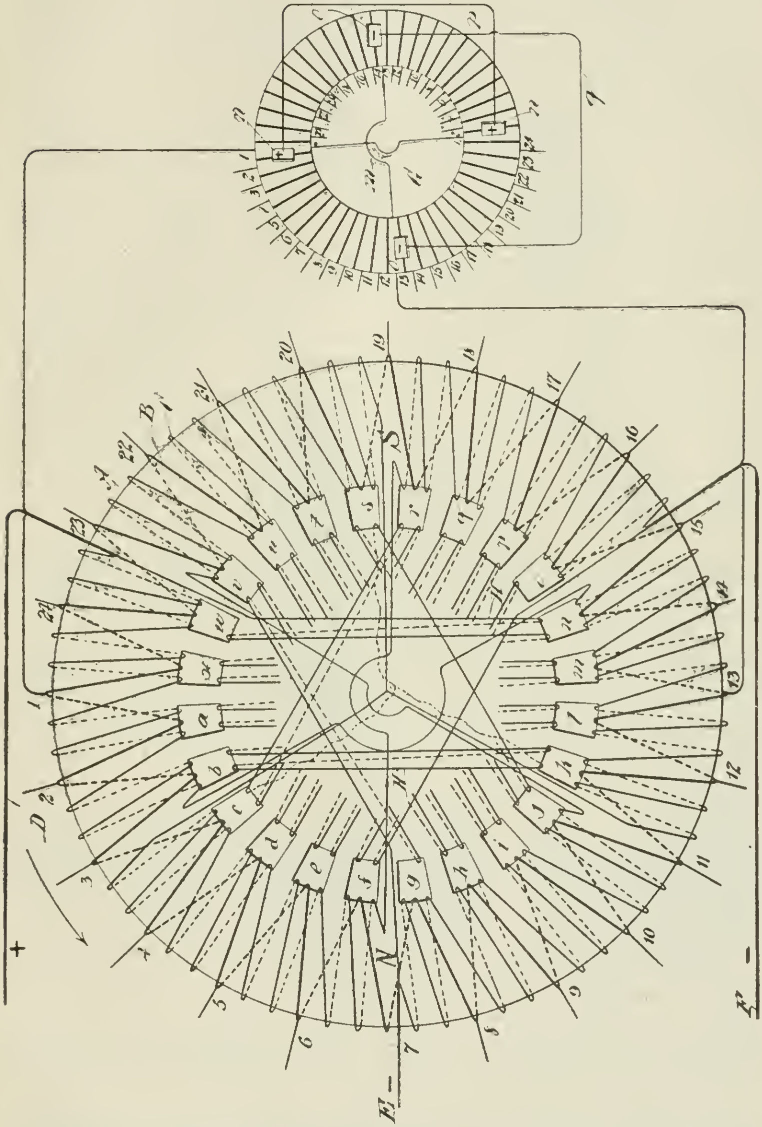


Plate XXII.—Humphrey's inductorium, with closed magnetic circuit. 1899.

laminated disks and punched with a series of holes *a*, *b*, *c*, etc., midway between the centre and the periphery. As

shown, the primary is wound for a three-phase current, both exterior and interior being wound, as shown, so as to produce a rotating field flowing from one side to the other around both sides of the circumferential portion, and returning through the centre. Only the exterior is wound with the secondary, which is passed through the holes and forms a closed Gramme ring. In this form there are no free poles at any time, the magnetic flux jumping from bridge to bridge across the holes *a*, *b*, *c*, etc., and cutting the conductors as they pass. Each of the wires *1*, *2*, *3*, etc., dividing adjoining segments of the secondary winding, is joined to the proper segment of the stationary commutator *G*, whose brushes are rotated synchronously by a donkey-motor. As shown, there are twenty-four armature segments and forty-eight commutator segments, so that opposite segments of the commutator are joined, and the brushes are rotated with half the speed of the field of the transformer, a four-pole motor being used for this purpose.

Thus far has the ring form of the inductorium advanced; we now pass to consider a new and different mode of effecting the same fundamental object—to wit, the multiplication of phases to a large number from an original two or three—an object of which we had almost lost sight; although looking again at the compact ring form of Plate XXII, we see that it is in essence a transformation of a three-phase into a twenty-four phase current before commutation.

Let $O X$, $O Y$ (Plate XXIII, *Fig. 1*) be vectors representing in magnitude and direction two equal electromotive forces in a primary circuit in quadrature with each other. We desire to transform these two E.M.F.'s into two other E.M.F.'s, $O x$, $O y$, also equal and in quadrature with each other. This, of course, is easily effected by the use of two ordinary stationary transformers with primary and secondary coils, wound in the ratio $O x : O X$.[77] Now suppose we wish to

[77] This resulting E.M.F. would, of course, be practically in opposition to the original E.M.F.'s $O X$, $O Y$, but they preserve the same relative angle with regard to each other, and their representation in the same axial directions do not affect the demonstration.

produce a new E.M.F. of the same strength Ox, but differing from it in phase by 45°. Let this be represented by Om. It is clear then that if we take a secondary winding On in the first transformer of a length equal to $On = Ox \div \sqrt{2}$

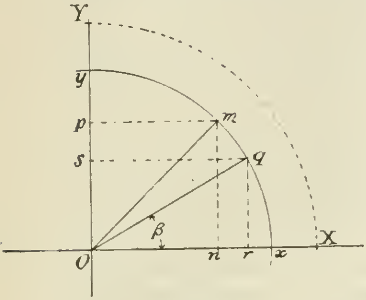


Fig. 1.

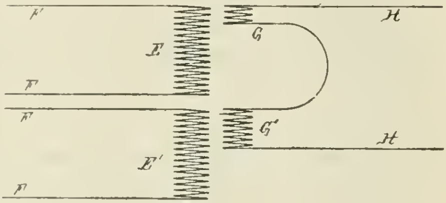


Fig. 2.

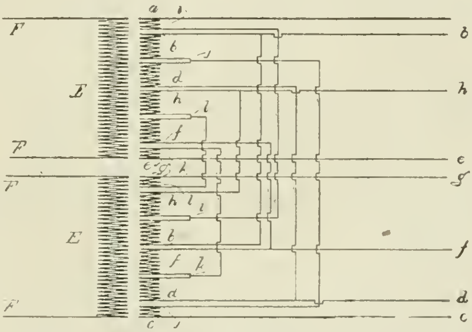
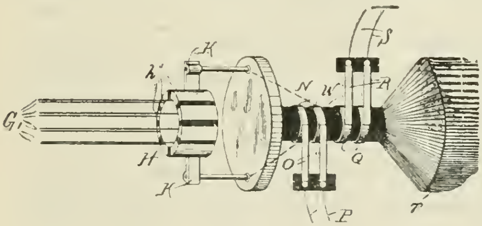


Fig. 3.



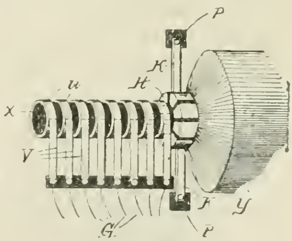


Fig. 4. *Fig. 5.*

PLATE XXIII.—Rowland's method of transformation for polyphase currents. 1899.

relative to OX, and place it in series with another equal length of secondary winding Op in the second transformer, we shall produce the desired E.M.F. In the same way a

secondary E.M.F. of any desired magnitude and direction Oq, making an angle β with Ox, may be produced by simply joining in series two secondary windings of lengths $O\,r = O\,q \cos \beta$ and $O\,s = O\,q \sin \beta$ wound upon the respective transformers. We may, of course, cause the direction $O\,q$ to lie in any of the four quadrants by reversing the relative directions of winding of the primary and secondary coils.

This is Professor Rowland's winding, exemplified in *Fig.* 2,[78] which shows one secondary coil so connected. A number of such double secondary transformer coils are wound, and connected up in a closed coil exactly like a Gramme ring, each point of junction being connected to a commutator segment. A transformer thus wound for an eight-phase secondary is shown diagrammatically in *Fig.* 3. In *Fig.* 4 the commutator is stationary, the brushes rotating, and the *D C* current is taken off by the slip-ring connections *O*; in *Fig.* 5, the commutator rotates and is connected to the transformer coils through a number of slip-rings *u*, one joined to each commutator segment. In the case given above, there would be only eight such segments and rings.

It is, of course, not necessary to use two independent transformers; a four-phase transformer of the spoked wheel or other convenient type may be used. In the case of only eight phases, they could all be produced from such a transformer by winding eight equal secondary coils upon the four spokes and the four rim-segments, respectively, as indicated above (page 266*). Nor is it necessary that the primary currents be in quadrature, in the general theorem; for theoretically, at least, the required derived phase could be produced from any two primary currents whose phases differ by less than 180°.

It will be seen that the Scott method of transforming two-phase into three-phase currents (page 267†) is a special case of the foregoing.

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[78] *Figs.* 2, 3, 4 *and* 5 are from the specification of his patent No. 628,358, of July 4, 1899.

*April number of this *Journal*.

†April number of this *Journal*.

An apparatus operating on the same general principle, but showing a large advance in practical construction, is that shown in a recent patent to Messrs. Hutin and Leblanc,[79] of Paris, and depicted in Plates XXIV and XXV. These ingenious inventors have taken a broader view of the problem, and the details for a three-phase apparatus with a forty-eight-phase secondary, and in fact the complete theory of the apparatus, have been worked out very beautifully by the inventors in sinusoidal equations. For these the reader is referred to their specification; the apparatus and its mode of working will, however, be briefly described.

It will be seen from *Fig. 1*, in which H_1, H_2, H_3 are the three primary circuits, and *1*, *2*, *3*, etc., the secondaries, that the principle lies in extending each secondary circuit successively across each of the three primary mains in a transformer winding of appropriate length. As there are forty-eight secondary circuits, this would make 144 transformer cores; but as one-half of these circuits are in opposition to the other half, we need but seventy-two cores, half the forty-eight circuits being wound in reverse direction. To conveniently dispose this great number of cores, the inventors arrange them on two sides of the chamber in which they are stored, each side containing thirty-six cores arranged in two stories, with six tiers of three cores each from front to back, as exhibited in the plan, *Fig. 2*, and the elevation of the cores shown in *Fig. 3*. These thirty-six cores are yoked together in three rows or divisions from front to back, magnetically separate from each other to avoid mutual induction. The three rows of cores from front to back each belong to a separate primary circuit, one of which, H_1, is shown in the elevation of one of the two frames composing the completed transformer, as connected to each of the twelve cores in the front row, while H_2 and H_3 are respectively connected to each core in one of the other two rows. Now, referring again to *Fig. 1* and the main theory, the disposition of the cores and windings is such that each secondary E.M.F., *1*, *2*, *3*, etc., will differ in phase by an angle

[79] No. 644,553, of February 27, 1900.

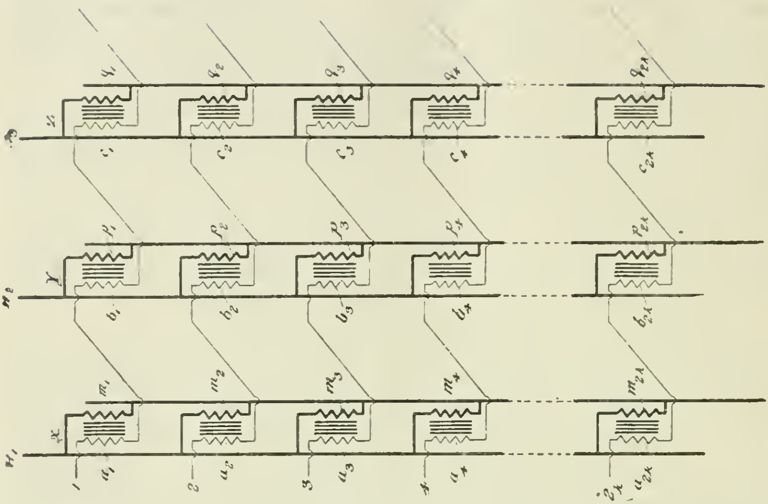


Fig. 1.

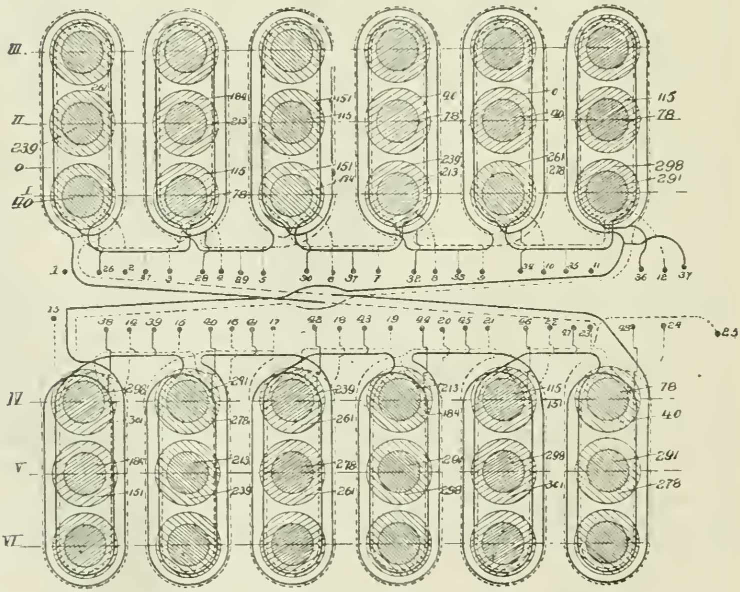


Fig. 2.

Plate XXIV.—Inductorium of Hutin & LeBlanc. 1900.

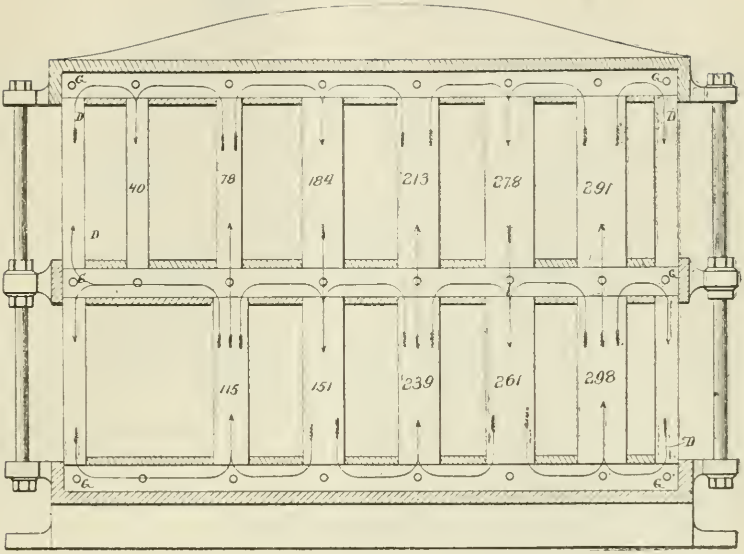


Fig. 3.

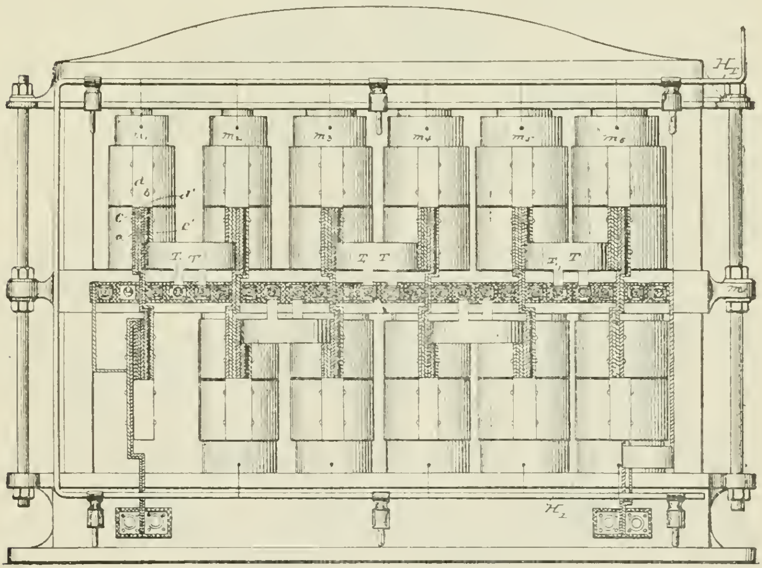


Fig. 4.

PLATE XXV.—Inductorium of Hutin & LeBlanc. 1900.

$$\frac{2\pi}{48}$$

from the one preceding. This is arranged, however, not by varying the winding of the secondary coils, but that of the primary, along with the areas of the respective cores, the primary turns being in inverse ratio to the areas of the cores. In *Fig. 2* the lower rows of cores are shown diagrammatically by large circles, and the upper row by small circles concentric therewith; but the actual areas of the cores are indicated by the figures attached to each core (*Figs. 2* and *3*). The actual secondary winding is then just as shown by the heavy and dotted lines (the latter representing the coils reversely wound), *Fig. 2;* a single turn of secondary circuit being taken around all three cores at once (making thus a total number of turns $144 \div 3 = 48$), and there being a commutator segment attached between each turn, as shown by the numbered dots *1* to *48*.

Fig. 4 is a general front elevation of one side (the *upper Fig. 2*) of the finished machine, showing the secondary connector bars *T* with tabs *T'* attached to the appropriate leads of the respective commutator segments, as indicated in *Fig. 2*.

The commutator is a rotating one, having forty-eight segments connected to the several cores by forty-eight slip-rings; in the patent drawing, a double commutator is shown, driven by a three-phase motor at each end of the shaft.

The last of the inductorium type which we shall here mention is one described in an earlier patent[80] to the same inventors, which operates upon a different principle from any of the machines hitherto described, and one no less ingenious and interesting than the last. (Plate XXVI.)

There are, in fact, two objects of the invention; the first of which aims to produce from a single-phase alternating current a unidirectional but *pulsating* current, which is not the result of mere reversal of direction, as in the common rectifier (page 211*), but which follows as far as may be a true

[80] No. 572,510, of December 1, 1896.
* March number of this *Journal*.

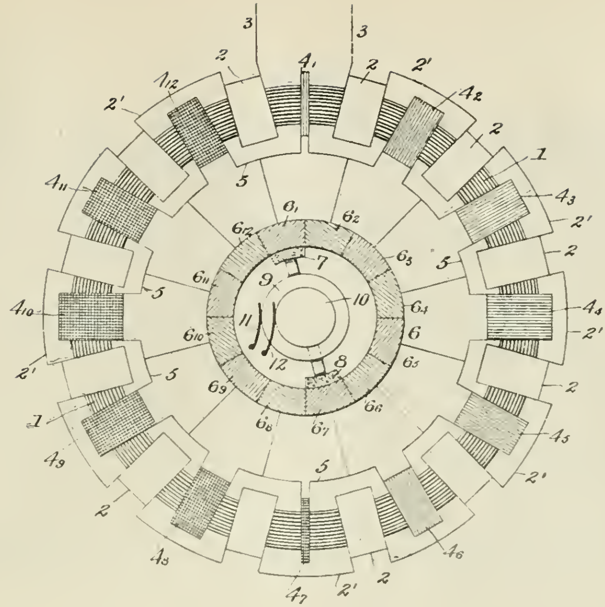


Fig. 1.

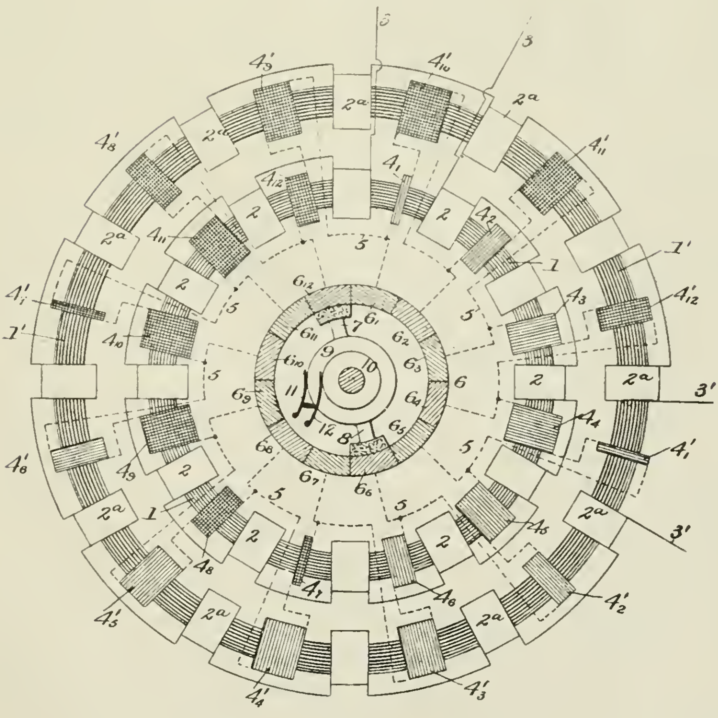


Fig. 2.

Plate XXVI.—Hutin & LeBlanc's ring inductorium. 1896.
Fig. 1, for alternating currents; *Fig. 2*. for two-phase (four-phase) currents.

sine law, the oscillation being between zero and a positive maximum (instead of, as in alternating currents, equal positive and negative maxima), and which has a frequency twice that of the primary; its zero and maximum points thus being simultaneous with those of the primary. There is thus no energy stored in the apparatus, magnetically or otherwise, to sustain the current flow during the zero periods of the primary current. Next, this pulsating current is added to another of the same sort, but so differing from it in phase that the sum of the two for all instants is constant, on the principle that the sum of the squares of the sine and cosine of any quantity is equal to unity. The principle of such constancy holds also, as is known, for any number of such forces differing from each other by a proper phase-angle.

Fig. 1 shows in diagram an apparatus by which the first of these objects is carried into effect. *1* is a ring or core of iron, wound with a series of primary coils *2*, all connected up in a single series and broken at one point, the terminals *3, 3* being connected to any suitable source of alternating E.M.F. These coils *2* will, it is obvious, operate to produce a circular magnetic flux in the core *1*, alternating in direction, but without free poles, exactly as in a choke coil or ordinary ring transformer. 4_1, 4_2, 4_3, etc., are secondary coils connected in a closed series, not wound, as in a Gramme ring, all in the same direction, but divided by the the line 6_1 6_7 into two halves, each of which is wound in the opposite direction, and the junctions of the coils all connected up to the bars of a commutator in the ordinary way. From this it is seen that the alternating flux set up in the core *1* will produce two equal and opposite E.M.F.'s in the opposite halves of the ring, and no current will therefore circulate in the ring, but a current may be drawn off from the brushes *7, 8* when in the position shown. These two currents, on account of the opposite winding, will also set up a circular magnetic flux, so that no free poles will be produced. Now, supposing the E.M.F. in the secondary coil to be at its maximum when the brushes are in the position shown, let the brushes be rotated clockwise with a fre-

quency equal to that of the current. Assuming for the present each coil *4* to be of equal size, when the brushes have reached the bars 6_2, 6_5, the E.M.F. will now be only that due to the four coils 4_2, 4_3, 4_4, 4_5, because the two coils 4_1 and 4_2 will be mutually neutralized, and the same is true of the coils 4_6, 4_7. In this way we reach, when the brushes have arrived at the bars 6_4 6_{10}, a condition in which all the coils oppose each other, and the E.M.F. is consequently zero. At the same instant the flux and also the developed E.M.F. in each individual coil is zero. Now when the brushes have reached the next segment, an E.M.F. is developed in the secondary coils in the opposite direction, but as the brushes have reversed their position the resulting E.M.F. at the slip-rings *11*, *12* will be in the same direction. The double reversal again takes place when the brushes have passed through 180° from the former zero point. Thus the current in the secondary circuit will be zero twice in a revolution, and will also be a positive maximum twice in a revolution; its E.M.F. is therefore always positive and has a frequency double that of the primary circuit.

If equal-sized coils are employed, the curve will take a zigzag shape composed of straight lines, if the number of commutator segments is supposed infinite. But we may give the coils such dimensions, as indicated in the drawing, that the curve shall be truly sinusoidal, or we may vary the width of the commutator bars to the same end.

When this coil is used alone, a choke coil of special construction is used by the inventors to diminish the pulsations in the secondary circuit. By. adding another coil (*Fig. 2*), whose impressed E.M.F. is in quadrature with the first, connecting each coil of one in series with a coil making an angle of 90° with it in the other, the two added E.M.F.'s produce a constant E.M.F. equal to the maximum developed in each coil taken singly. Only a single commutator is necessary for this arrangement. With a three-phase primary, three rings are required connected in like manner, but dephased from each other by an angle of 120°.

This machine, as shown in diagram, has a stationary

commutator with rotating brushes; but, in practice, the inventors prefer to couple it by numerous slip-rings to a rotating commutator, provided with stationary brushes. Such a commutator is shown having n slip-rings and $3n$ segments, each ring being connected at three points 120° apart; the synchronous motor driving it has therefore $3n$ pairs of poles. The brushes may be thus set at 60° apart if desired.

It will be observed that this machine operates on a fundamentally different principle from those previously described, as no rotating magnetic fields nor polyphase currents are produced in either ring, nor are the number of phases increased.

All the types of machine above described are completely reversible, except the single-ring type of that last described.

The theory of these machines is very elegant, and their theoretical advantage over other types, such as the rotary transformer, undoubted. Practically, stationary transformers,—always necessary with the latter where high pressure is used—are replaced by the stationary part of the machines themselves,—which, so far as can be seen, *ought* to be of substantially the same efficiency; while, again, the rotary transformer is replaced by a mere rotating commutator—with numerous slip-rings, it is true, but still diminutive with respect to the total power transformed—using no power but that absorbed by a small donkey-motor.

The ultimate question is, however, one of practice. What is its practical efficiency, and what are its defects?—these are the questions put by the users. The machines are of so recent a date (in their improved form at least) that very little data is yet at hand, so that little can be said on this point. So far, the only objection urged against it is sparking at the commutator; but this is probably more prejudice than fact. It is claimed by its abettors that the sparking can be regulated in precisely the same way as a continuous-current dynamo—by giving the brushes the necessary lag or lead; and this does not seem unlikely. It seems rather that the notorious defects of the old continuous-current inductorium, which was never guilty of an

alternating current in the true sense, have been fathered upon the new and different type. So far as facts go, it is generally understood that a number of machines of the Hutin-Leblanc type are working on the continent of Europe, and giving no trouble in this direction. We may add further that, according to Professor Thompson,[81] Mr. Kolben, of Prag, reports having used one of these machines continuously for eighteen months, and with "excellent results." The machine transforms three-phase to continuous currents, which are used to charge accumulators. "There is," he continues, "no sign of sparking at the brushes (which are fixed) even with a varying voltage. Its efficiency is at least 95 per cent., including allowance for losses in the stationary transformers, and its cost and maintenance much smaller than that of a rotatory converter." (Why stationary transformers were used does not appear.)

We must, of course, await further information before passing final judgment on these machines, but in the meanwhile it seems safe to predict that they will in the near future prove a formidable rival to the one-coil rotary, if they do not ultimately displace it altogether.

[*To be concluded.*]

Mining and Metallurgical Section.

Stated Meeting, held Wednesday, January 9, 1901.

UTILIZATION OF THE WASTES FROM THE USE OF WHITE METALS.

By Joseph Richards, Member of the Institute.
(Being the Address of the Retiring President.)

It is now more than forty years since I first seriously considered that in the use of what were then called "waste products" from metallurgical operations there was a field almost untouched, and in treating the subject of my paper this evening I shall confine myself chiefly to an account of my own work in this line.

[81] *Jour. I. E. E.*, V. 27, p. 737, Nov. 24, 1898.

The white metals to which I refer are silver, tin, zinc, antimony, bismuth, lead, mercury and their various alloys, and my paper will treat of the methods which I have found most serviceable in utilizing the waste products resulting from the use of these metals either singly or as alloys. In reference to the utilization of silver wastes, the subject is so well known that I will refer to this only in connection with the recovery of silver from plated ware in another part of my paper.

First in order, I will relate my experiences in connection with

THE UTILIZATION OF TIN CLIPPINGS AND GALVANIZED-IRON SCRAP.

When first I turned my attention to the subject, I found that large quantities of tin scrap and galvanized iron were every day carted to the dumps.

I found that the average coating on scrap tin, as tin on tin plate, was 3 per cent.; that the iron if properly cleaned could be used in the nobbling furnace and in the puddling furnace; that the use of galvanized iron was a necessary part of the process; and it looked so encouraging that we decided to build a plant to work it on a commercial scale.

I procured a half dozen of the large lager beer casks used for storage, and which are about 6 feet in diameter and 6 feet deep. After removing the heads, they were placed in the ground in a semicircle and a crane was rigged up that commanded all the tanks.

In the first tank was charged hydrochloric acid; in the second, water; in the third, water with a little lime; in the fourth, water; and in the fifth, a solution of copper sulphate.

The plan of work was to fill a large wooden cage that would hold loosely about 200 pounds of the clippings. This was swung on the crane and placed in No. 1 tank. In ten minutes' time the cage was raised and the clippings examined to see if the tin was dissolved. If so, the cage was then lifted out of the acid tank and another cage filled with clippings took its place. The cleaned scrap was

washed in the water tank No. 2, lifted up and down to well wash it, and then immersed in the lime tank, No. 3. This neutralized all the residual acid that was left in the pores of the iron. The untinned and limed scrap was then moved to water tank No. 4 for a final washing, then plunged for a moment, just enough to submerge it, in the copper sulphate solution, then immediately removed. The object of this treatment was to form an exceedingly thin film on the iron to prevent the rusting of the clean iron, which is so sensitive when exposed to the air that it will almost instantly cover itself with rust. The cleaned scrap was compressed in a drop press into balls, and in this form was shipped to the iron works and worked into blooms for sheets, commanding a price of from $10 to $12 per ton.

After the process had been continued for some time, all the acid in No. 1 tank would become neutralized and we would have a solution of chloride of tin.

The process of tin cleaning stopped here for a while. We then took a cage of galvanized iron scraps, filling the cage loosely. When the zinc came in contact with the tin solution, the metallic zinc took the place of the tin, forming zinc chloride, and all the tin was precipitated as metallic tin, in a finely divided state. We worked this plant successfully for some time, recovering, when melted into ingots, about 600 pounds of tin fron 10 tons of scrap. The recovered iron commanded $10 per ton and the zinc chloride $20 per barrel, for disinfectant purposes and for treating wood to make it fireproof.

We finally closed the works because of the objectionable vapors that annoyed our neighbors, with the intention of rebuilding on the swamps near Chester, but other things prevented us doing so. I yet think it is the best and most profitable means of utilizing this scrap, especially if electricity is used for the disposition of the tin.

WASTES FROM THE GALVANIZING PROCESS.

While working up the tin scrap, I turned attention also to the wastes from the galvanizing process. In order that you may understand the problems involved, I will give a brief description of the process as then and now practised.

The trade term "galvanizing" relates to the coating of iron with zinc. In order to do this the iron article to be coated must first be surface-cleaned from all dirt and other impurities, so as to present a perfectly clean metallic surface. If any dirt, scale or oxide remains on the surface, the zinc will not adhere to that part, and imperfect work will be the result. This cleaning is done by immersing the article in a bath of sulphuric acid and water, well washing in water, plunging in hydrochloric acid for a short time and drying. The article is then put into the bath of molten zinc. If sheets, or similar articles that will not hold much water, are being coated, the drying may be dispensed with to advantage. The galvanizing tank, or bath, as it is called, is of necessary size for the articles to be submerged, varying from ½ ton to 30 tons capacity.

This tank is usually oblong in shape and is divided on its surface, by a longitudinal partition, into two parts. On one side of the division a suitable flux is placed which will dissolve the oxide of zinc on the surface or prevent its formation. The flux used is ammonium chloride, or, in trade parlance, sal ammoniac.

The other side of the bath is kept clean by continually skimming off the oxide of zinc as fast as it forms. In this skimming of the pot considerable shot metal is unavoidably removed with the oxide.

The side with the sal ammoniac soon becomes covered with a thick black scum which consists of the dissolved oxide, which has partly decomposed the ammonium chloride and formed a double chloride of zinc and ammonium.

The sal ammoniac must be fed continually to the top of the pot so as to keep the surface of the molten zinc clean and free from oxide, or else the oxide will adhere to the iron surface and affect injuriously the finished product by leaving spots uncoated with zinc.

By the continued addition of sal ammoniac the scum accumulates on the top of the pot and soon gets too thick for the workman to push his plates or other articles through, so a portion is removed from time to time. This yields on one side a waste called sal-ammoniac skimmings, and on the other side, zinc oxide or zinc skimmings.

Yet another by-product is made that is called zinc-slab dross. This is formed by the continued washing away of a portion of the iron that is being galvanized; for zinc in a molten state will alloy with iron, so that as soon as the iron becomes as hot as the bath its surface begins to dissolve in the zinc. If from accident or design a piece of iron is left in the bath after this dissolving process commences, it will in time be entirely dissolved. We often find bolts, nails, castings, etc., from the bottom of the bath that are nearly all, as it were, eaten away or dissolved in the zinc.

This addition of iron to the bath forms an alloy of iron and zinc that is of greater specific gravity than the zinc itself and which falls to the bottom of the bath. If the bath is run hot it collects very fast, but under ordinary circumstances a bath of the usual size for pipes or sheets will make a ton of this dross in a week.

In order to have depth enough to do the work properly, the dross must be removed. This is usually done every Saturday afternoon. A large spoon is used, perforated with holes to allow the zinc to drain out, and the semi-fluid dross is pasted into moulds, smoothed off with a shovel, and is then the slab dross of commerce.

Thus it appears that we have three by-products: Sal-ammoniac skimmings from one side, zinc oxide or zinc skimmings from the other, and slab dross from the bottom of the bath.

Sal-ammoniac Skimmings.—At the time named, 1871, there was no use for the sal-ammoniac skimmings, and at all the works where I inquired they were throwing it away.

I commenced experiments to separate this waste into three parts, for I knew that the sal ammoniac, if recovered, could be used again, also the metallic zinc, and I thought I could find a use for the zinc oxide if it could be freed from its impurities. Simple as this problem appears, it was not solved without much labor. I found by leaching these skimmings with hot water and steam that I got all the zinc chloride and ammonium chloride in solution. This I evaporated down and recrystallized for use again on the bath. The residue, after washing with water and drying, I

found to contain zinc oxide with some little dirt and shots of metallic zinc. I placed this in a tumbler, or octagon-shaped barrel, with the joints not very tight. After revolving for some time, all the oxide lumps were ground to powder and the metallic particles were nice and clean, ready for melting on the top of a pot of molten zinc. The oxide, in the shape it was in, was worth $30 per ton to the makers of zinc white paint.

I had to induce the paint men to buy this new product, but they were surprised, on using it, at its value to them, and willingly gave me the above price.

The average yield was:

	Per Cent.
Zinc	20
Ammonium and zinc chloride	30
Zinc oxide	35
Iron scale and dirt	15

I visited the galvanizing iron works, bought up what waste I could and contracted for future deliveries for one, two or three years in advance. At the McCollough Iron Company's works in this city we dug up a large part of their yard, where the stuff had been thrown for filling, and it realized about $300 a car load. Also in Pittsburgh, I found a dump where it had been thrown for years, and though it was badly mixed with dirt and ashes, I gave them $50 a car load for all that they could recover. At Winches' old iron mills in this city many of the tanks had been cut up and the "salamanders" of dross had been used for filling up the Delaware River wharves. All that was left I purchased. The largest lump I ever treated was one that yielded, when melted and refined, 25,000 pounds of good spelter.

The oxide found ready sale to the Bergen Point Zinc Company, who took all I would send them for years, but soon my men were approached and double wages bought my secrets. To-day the process is generally known in the trade and is practised by the largest zinc oxide makers in this country and in Europe.

Zinc Oxide Skimmings.—This, as previously mentioned, consists of zinc oxide and shot metal. I had no particular

trouble with this waste. All that was needed was to place it in the tumbler or barrel before described and then melt the resulting shot metal in our furnace, pouring into suitable ingots for use again.

I found at Trenton one accumulation of several hundred tons of mixed skimmings that they had tried to roast for zinc white, but the sal ammoniac and the zinc chloride rotted thousands of dollars' worth of flannel bags and the operation had to be abandoned. By my process it was all used up profitably.

The galvanizers now keep their skimmings separate, are very careful of them, and last year the price for this product was advanced from $15 to $40 per ton, according to its quality.

Zinc Dross.—We now come to the third and most important residue, zinc dross, or zinc contaminated with iron. Here, I would preface my remarks by saying that, as a pioneer in this industry, I had to gradually feel my way. All the work done was original with myself. I had no outside help from books, and from that day to this my work has been one long experiment. I feel that in the limits of this paper I can only just touch on the successful part of my work, without recording the many failures.

At the time I began working in this line, the greater part of the slab zinc dross was sent to England. The only known way of using it to advantage was to distil it in retorts just as zinc is originally made from the ore.

My first experiments were directly in this line. I built a retort furnace and made very good commercial zinc, but the process was very costly. I immediately began devising ways and means for recovering the zinc without so much cost and so expensive a plant. I found that the distilling cost from $30 to $35 per ton.

Many were the experiments I conducted; my idea being that if the dross was melted in a suitable furnace I ought to be able to separate the iron from the zinc when in a molten state.

First, I took a crucible, and when the metal was melted I injected cold air to oxidize the iron, with the result of

oxidizing the zinc; then hot air, but with still quicker oxidizing of the zinc. Steam was a slight improvement; superheated steam was better; salts of the alkalies all acted on the zinc, but sulphur gave good results. I continued these experiments on a large scale, using larger furnaces, so that I could treat several thousand pounds at a time.

Once I had a very interesting experience. Thinking that the zinc and iron alloy should be as hot as possible so that the sulphur would more readily attack the iron, the temperature of the metal was gradually raised, but too high, for as soon as the sulphur was immersed it fired the pot and immediately the center rose in the air to a height of several feet and lumps of molten zinc, all on fire, flew in a perfect shower. It was a little volcano threatening death and destruction to all around. My men ran away; I seized the fire hose and by sprinkling only on top succeeding in quenching the fire. It will suffice to add that the experiment was never repeated.

To sum up my results, I found that cyanides answered the purpose admirably, but the cost was prohibitory. Sulphur and superheated steam were both good.

I built a plant to treat the dross on a large scale and made a very simple furnace (see sketch) to super-heat the steam and a tube for feeding the pot with chemicals. This furnace is the same as those now in use except that they are now built much larger. So successful was the process that, to protect ourselves, we were obliged to patent it.

As before stated, I wanted to treat the molten metal with superheated steam and also wanted to use the cyanides and the sulphur. Accordingly I devised a method which readily overcame all the difficulties of their application. We all know that potatoes are composed largely of water and that leather scrap is used in making cyanide, so I used a mixture of sulphur, potatoes and leather scrap, and introduced the mixture into the bath by means of an injector like that shown in the accompanying sketch. This could be held under the molten metal and soon became hot enough to generate steam, distil the sulphur, and throw off the gases from the leather. The pot distils all it wants,

the steam keeps the pot boiling, and about fifteen minutes cooks the pot of molten metal.

I have here samples of the dross before melting, after melting and before treating, after treatment; also samples of the finished product and of the residue.

After the pot is boiled it is necessary to allow it to settle awhile, the oxides coming to the top and the new iron and zinc compounds going to the bottom. After it has properly settled, the good metal is bailed into moulds and the residue is dug out with a shovel. The analysis of our refined spelter given below shows it to be nearly equal to the virgin spelter in quality.

	Zinc.	Lead.	Iron.
<s> Spelter	98·35	1·50	·15
American Western		1·50	
Average German		1·60	
Silesian		2·10	
Blyberg		1·75	

This analysis of <s> spelter was made from an average of forty car loads.

About this time I became acquainted with the late Colonel Frishmuth, and helped him in his experiments to make aluminium, and began experimenting to ascertain the effects of aluminium when alloyed with zinc. I found that the addition of $\frac{1}{1000}$ part of 1 per cent. of aluminium to zinc was immediately and favorably shown, and it occurred to me that an alloy of zinc and aluminium might be used to advantage in the galvanizing pot, and as a finishing touch in our refining process. The results of these experiments were embodied in patents for use of aluminium in the refining of zinc, and in a patent for the use of aluminium in the galvanizing bath.

The action of the aluminium is, doubtless, to remove the oxygen contained in the molten metal, for when sufficient aluminium is added to make it fluid, and a sample is taken for analysis, no aluminium is found, but any addition after that point is reached is readily detected, and an excess is of no advantage to the metal. Though the quantity used is so small that no action could reasonably be expected, yet it is distributed so quickly all through the mass that in a few

minutes, say, from five to ten minutes, we can commence pouring, while before we used the aluminium it required from one-half hour to two hours for proper settling to take place.

If a sample of untreated metal be taken from the bath, which will not run half way down the mould, it will, upon the addition to it of a little of the aluminium alloy in the ladle, become so liquid that it fills the mould and flows backwards and forwards like water. I have here samples showing this effect.

In using the aluminium I find it best to make an alloy of 98 per cent. zinc and 2 per cent. aluminium, and for the galvanizing bath 5 to 10 per cent. aluminium. So satisfactory have been these results and so commercially practical that we have treated about 100,000,000 pounds of zinc dross by these processes. Even this result was not all we could wish, and, from time to time, as they have suggested themselves, further experiments have been made with varied success.

We found a demand for a better quality of spelter, so we melted our <S> brand and subjected it to the same process a second time, calling it "Double Refined." You will see from the sample shown and the analysis given that the result wished for has been obtained. The analysis shows from 99 to 99·75 per cent. zinc, the only impurity being a little lead.

It was thought that a chemically pure spelter could be made by again refining the "Double Refined," but we were not successful in making it higher than 99·85 per cent. zinc. I then requested my son, Prof. Richards, of Lehigh University, to give his attention to what could be done in refining by the use of electricity, and, after considerable work, we were encouraged to build a plant on a large scale to fully demonstrate its worth. We had a 40 horse-power engine and dynamo, and succeeded in producing large quantities by this means. I believe it was the purest spelter ever made. The following analysis was made from a 2,000-pound sample by Prof. J. W. Richards:

Zinc	99·981
Iron	·007
Aluminium	·002

This electrolytic metal was absolutely free from arsenic or other impurities; its manufacture was not profitable because of the low market value of zinc.

The *scrap zinc* of commerce we melt in our pot furnace and treat in the same manner as the dross, to remove its impurities.

Battery zincs that contain mercury are put in the pot at night. A suitable cover or lid, with condenser and spout, is attached to the pot, by means of which all the mercury is recovered without danger to the workmen.

One other thing I will mention, though a little foreign to my subject. While working with aluminium I discovered a hard alloy which is proving of so much use that I have brought several samples for your inspection. These include scale-beam castings made by Mr. H. Troemner. (I may say that Mr. Troemner has successfully used it, not only for his small balances, but also for the large scales for the mints of Philadelphia and Washington, the New York Treasury and other notable work.) So rigid is the alloy that this beam, which is only intended to bear a weight of 4 ounces, has been tested up to 42 pounds before any appreciable deflection was noticeable. The metal works equally well as the finest brass or bronze under the tool.

In this informal talk I have only touched on the most important and successful work done in this line in the last thirty years.

I thank you for the courtesy that you have extended to me, not only this evening, but at all the meetings of the section at which I have had the pleasure of presiding.

[*To be concluded.*]

Mechanical and Engineering Section.

Read at the stated meeting held Thursday, March 14, 1901.

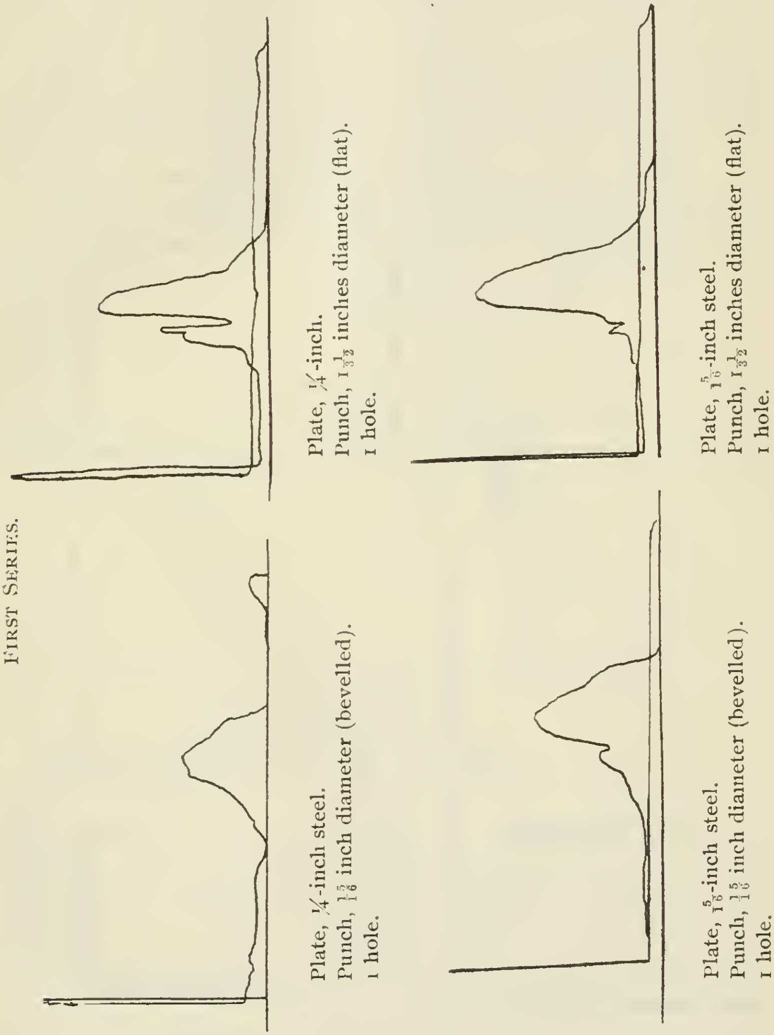
THE FLOW OF METAL.

BY HENRIK V. LOSS, M.E., M.A. Soc. M.E., Member of the Institute.

A little more than a year ago I had the honor and privilege of laying before you a synopsis of a series of experiments on the "Flow of Steel," covering researches made at intervals during the last ten to fifteen years. The Institute was pleased to send out advance copies of my lecture, thereby securing a very thorough and exceedingly interesting discussion. It gave me great pleasure to know that the major points covered by my work found such liberal and hearty reception, and that the only chapter to which any exception was made at that time was the one covering the resistance to punching. Several of the learned members of this section criticised my assertion that the ordinarily accepted and standard ultimate for punching steel should be reduced 30 per cent. or more. I told the members of the section, at the time, that the strangeness of this result came to me originally with as much surprise as it then did to them, and there seemed to be a desire on the part of several of the engineers present during the evening to inaugurate a series of individual and separate experiments, with a view of proving or disproving my statements. The burden of the argument seemed to be that punching could not possibly require less power than shearing. I shall not discuss that aspect of the case to-night, but will confine my arguments to the field of my original assertion, viz., that the accepted power to punch steel is decidedly an unnecessarily large one.

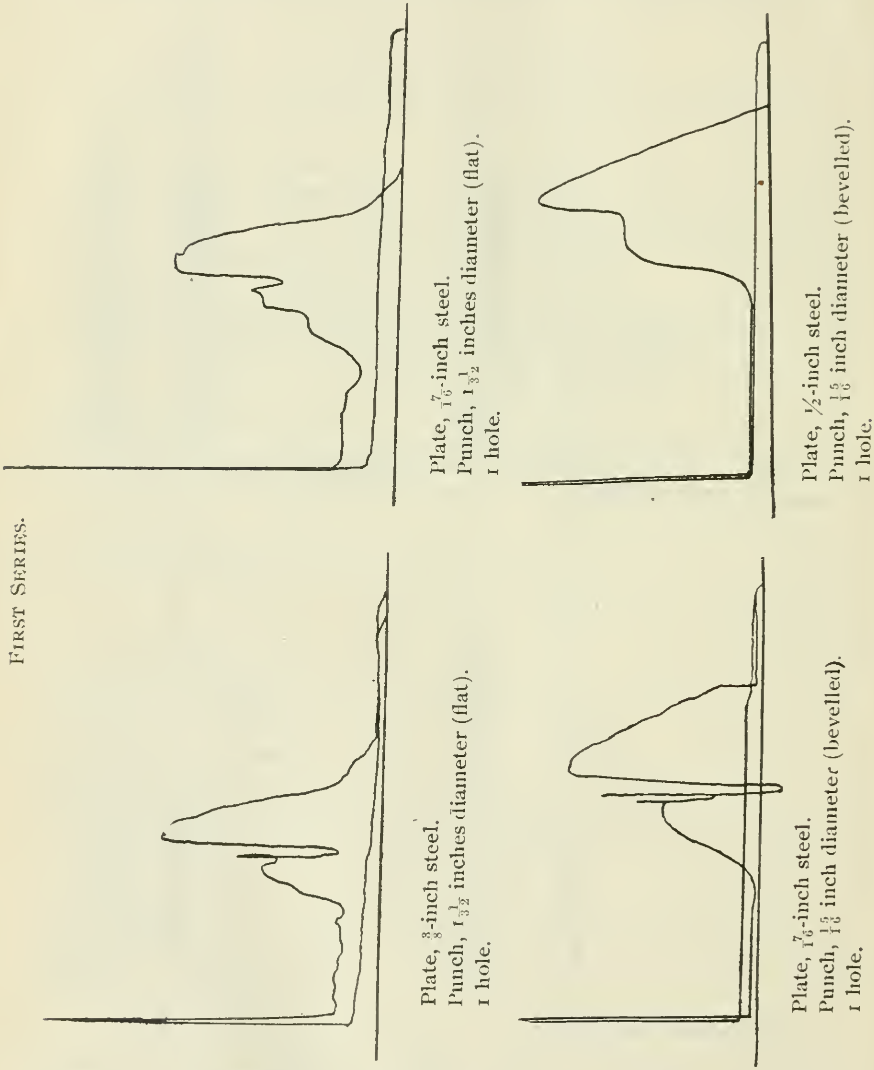
I frankly admit that when presenting my last experiments in this particular field I did so aiming at nothing more than to lay certain new facts before you, having no intention whatever of explaining their causes, as, up to that time, I had not been able to analyze them myself.

This evening, in adding whatever new data I possess, I wish to accompany them with the expression, as my own conviction, that the reason for the low ultimate for punching



lies in the fact that the punching machinery as hitherto used, and with which experiments have formerly been made, were power punches, possessing great speed of penetration,

while the experiments conducted by me have all been confined to hydraulic machines, where the velocity of the flow of metal during the process has been entirely under the



FIRST SERIES.

Plate, $\frac{7}{16}$-inch steel.
Punch, $1\frac{1}{32}$ inches diameter (flat).
1 hole.

Plate, ½-inch steel.
Punch, $\frac{15}{16}$ inch diameter (bevelled).
1 hole.

Plate, $\frac{3}{8}$-inch steel.
Punch, $1\frac{1}{32}$ inches diameter (flat).
1 hole.

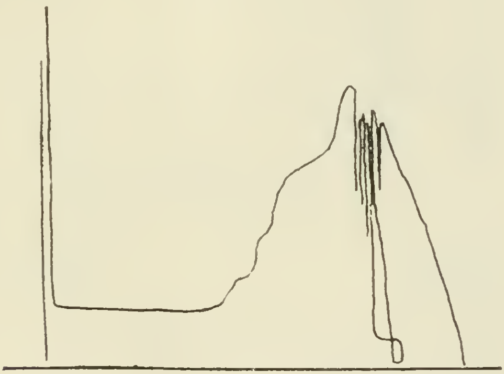
Plate, $\frac{7}{16}$-inch steel.
Punch, $\frac{15}{16}$ inch diameter (bevelled).
1 hole.

control of the operator. Speaking in a general way, I find from observation that the speed during the actual punching was from three to five and six times as great on a power

machine as on one driven by water pressure, and herein, undoubtedly, lies the solution of the problem. With this in view, it seems to me that the proper way to build a power punch is to have at least two different speeds—a *slow one for penetration and a quicker one for the return movement.* It has also lately come to my notice that some of the original experiments made by Messrs. Hoopes & Townsend, a number of years ago, were based upon this principle, and that the large nuts penetrated by small punches were only made possible upon the above-mentioned basis.

In laying before you my experiments, made since my last paper, I wish to say that the present ultimates are a little

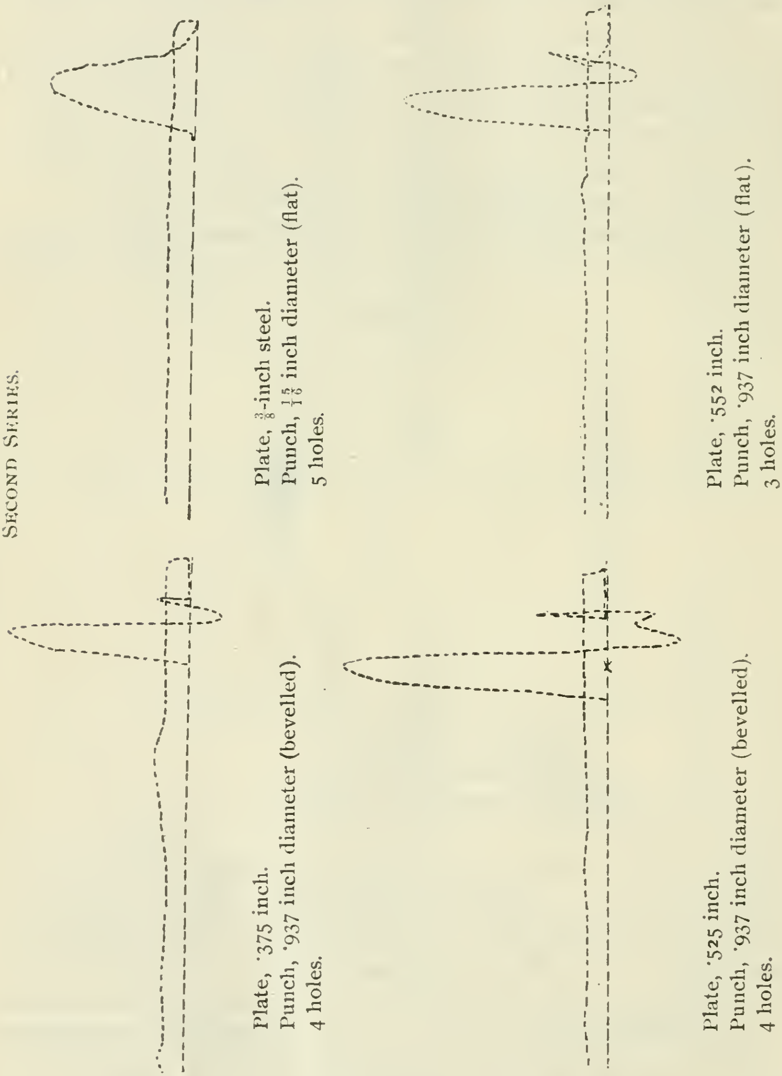
FIRST SERIES.



Plate, $\frac{9}{16}$-inch steel (full).
Punch, $\frac{15}{16}$ inch (bevelled).
Time, 15 seconds to penetrate.
1 hole.

higher than those originally given. The reasons for this may be many; possibly a little higher carbon steel, or a little more resistance in the machine upon which they were conducted, as compared to the multiple machines used in my previous work; or again the fact that our plates are all a little below size. In my former experiments the plates were not micrometered, having been given the benefit of the full round dimension, while with the data given you tonight the sheets have been more carefully measured up. With bevelled punches the original experiments averaged

about 35,000 pounds per square inch, while the data as given on the table below give about 42,000 pounds, increasing with the thickness of the plate. Flat punches gave about

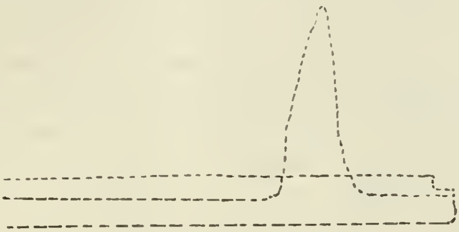


25 per cent. in addition, or about 40,000 to 42,000 pounds for old punches (and somewhat less for new ones), while the present experiments give about 45,000 to 46,000 pounds. It

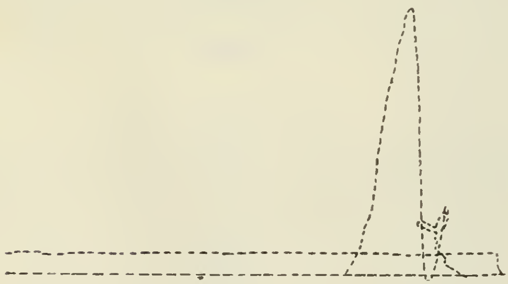
is also seen that with a flat punch the ultimate seems to be nearly constant and not depending upon the dimension of the plate; and, furthermore, it is interesting to note that when $\frac{1}{2}$-inch or $\frac{9}{16}$-inch plate is reached, the effect of the bevelling disappears, the ultimate being the same for both flat and bevelled punches.

This is in perfect harmony with my results found on shearing, which were that with $1\frac{3}{4}$-inch or 2-inch plate the beneficial effect of a bevelled knife disappeared.

SECOND SERIES.



Plate, ·552 inch.
Punch, ·937 inch diameter (bevelled).
3 holes.



Plate, ·552 inch.
Punch, ·937 inch diameter (bevelled).
4 holes.

The ultimate of the steel tested was about 60,000 pounds per square inch, and made by the basic open-hearth process.

I have very little more to say, having confined my work exclusively to meeting your criticisms upon the subject of punching. If any one of you should have conducted any

similar experiments, I should be very much pleased to know the results. I want to give to you to-night, for your own inspection, the original cards upon which the figures are based. They were taken at two different works, both belonging to the Pressed Steel Car Company in Pittsburgh, and conducted by two different men, but, withal, you can see how well they agree. The subject is an important one, as we all know, and when a year or more ago I was confronted by men of your standing and ability taking a strong stand in opposition to the results attained, I felt it my duty to proceed with the work. It is perfectly natural and justly right that our text-books, representing accepted standards for years and years, shall be respected, only to be thrown aside when refuted by indisputable evidence, and if my work in the field of "The Flow of Steel" has merited the recognition of my profession, I shall consider myself fully rewarded for my task.

AVERAGE ULTIMATES.

Thickness of Plate. Inch.		Bevelled Punch. Pounds Per Square Inch.	Flat Punch. Pounds Per Square Inch.
1/4	First series	40,000	49,600
	Second series.		
5/16	First series	39,500	46,000
	Second series.		
3/8	First series.		
	Second series	42,800	30,000 (?)
7/16	First series	41,150	41,000
	Second series.		
1/2	First series	42,400	
	Second series	44,100	38,500 (?)
9/16	First series	45,600	
	Second series	45,750	45,500
	Third series	45,000	

Figures under flat punch for $\frac{3}{8}$-inch and $\frac{1}{2}$-inch material (second series) were taken from a plate which was not micrometered. That they are somewhat lower than the rest may be caused by the character of this special sheet, and also that it may have followed the standard rule of being undersized.

PHILADELPHIA, January 15, 1901.

DISCUSSION.

MR. JAMES CHRISTIE.—It is to be regretted that during the admirable experiments of Mr. Loss, on the flow of metal, especially in those relating to the resistance to punching and shearing, that the element of time was not more accurately denoted.

It is obvious and well known that the resistance to flow or rupture of solid bodies is affected by the velocity of the movement. It has been asserted that if pressures exceeding the elastic limit were applied to material, through a punch for example, and sufficient time allowed, that perforation would ultimately follow. It is very well known that in the ordinary operation of testing by tension, the velocity with which the pull is exerted, exercises an important influence on the result; extremely low pulling speeds showing much lower tensile resistance than is indicated by higher speeds. Therefore, in order to discover exactly the comparative resistance to punching and to shearing, as touched on by Mr. Loss in his earlier paper, uniform velocities of movement should have been obtained as a necessary preliminary. The whole subject as presented by him has, however, been a very instructive one, and has yielded much information in this matter, not heretofore made public.

MR. LOSS'S REPLY.

MR. LOSS:—Referring to Mr. Christie's remarks on the question of speeds with which my experiments on punching and shearing were made, I have already fully stated to-night that herein lies the solution of the problem of low ultimates. I have indicated in connection with my last experiments, and which have been laid before you to-night, the speed of the punching, this being from $\frac{1}{3}$ to $\frac{1}{5}$ of that used in geared power machines.

As to the velocity used in shearing, however, I wish to say that they were practically the same, viz., a little higher for very thin dimensions, becoming slower, even up to the point of stalling the hydraulic press for the greater thicknesses, and in this last instance producing a card similar in effect as the punching card given to you to-night, and to

which card was attached a note, giving fifteen seconds as the time for penetration.

I think, however, that the aim and purpose resulting from my experiments, and to which I wish to call the attention of the Institute, have been misunderstood. I have stated in my paper this evening that the "accepted power to punch steel is decidedly an unnecessarily large one," but have made no criticism regarding the truth or error of results previously found by other investigators in this field.

It is most decidedly the province and duty of the engineer to procure the best and most economic results with the least expenditure, and when it was demonstrated not merely in an experimental or laboratory way, that practical punching machinery can be constructed upon certain principles which will allow them to perform 30 per cent. to 40 per cent. more work with the same expense, the result is one which the engineer certainly ought to heed, and it is this particular aspect of the case to which I want to call the attention of my fellow members of the Institute.

MACHINERY AND THE MAN.*

BY ALEXANDER E. OUTERBRIDGE, JR., Member of the Institute

The substitution of automatic or semi-automatic machinery for hand labor in industrial establishments has progressed so rapidly and has attained such large proportions, more especially in this country, during the past few years, that the subject is attracting much attention, and a wide diversity of opinion is expressed by students of industrial economics, employers and others, as to the probable influence of this far-reaching evolution upon the future intellectual development and material welfare of the wage-earner.

An address was recently given by a well-known teacher of economics upon the present aspect of labor in this

* An address to graduating students of the Schools of Drawing, Machine Design, and Naval Architecture, of the Franklin Institute, April 26, 1901.

country, and it was an able exposition of the views of one who has apparently studied the subject mainly from a theoretical and scholastic point of view. According to this authority the extensive substitution of automatic machinery for hand labor, now evident in all trades, is, of necessity, more or less detrimental to the intellectual development of the wage-earner, since the work which he is called upon to perform is reduced to the simplest routine operations involved in feeding a machine with raw material; that the monotony of his task is very depressing, and that the modern system of minute subdivision of labor develops a hopeless feeling in the mind of the operative, because he knows that there is little or no opportunity for him to become a skilled master of any trade through his daily work; that in the old days of the "apprenticeship system," when boys were indentured to masters and taught the principles and practice of a trade, there was more incentive to ambition, and, consequently, a quicker intellectual growth of the young mind, and a keener desire on the part of the youth to become a thorough workman. In a word, we were told that the modern system is injurious to the progress of the wage-earner. This is, perhaps, a natural view for one to take who looks at the subject from a theoretical standpoint only, but daily observation in large industrial works, covering a period of years during which a revolution has occurred in methods of conducting manufacturing industries, has given me a different opinion, based upon a different point of view; moreover, long before the invention of modern automatic machinery, and even before the birth of the factory system, similar views to those which have been given were expressed by the best known writers on economics. In 1776 Adam Smith, in his great work, "The Wealth of Nations," said:

"They [the working people] have little time to spare for education. * * As soon as they are able to work they must apply to some trade by which they can earn their subsistence. That trade, too, is generally so simple and uniform as to give little exercise to the understanding, while, at the same time, their labor is both so constant and so severe that it leaves them little leisure and less inclination to apply to or even to think of anything else."

The elimination of exhausting manual labor by the substitution of powerful machinery for puny arms has emancipated labor in our day from its hardest tasks, and has given to the worker both inclination and leisure for the development of his intellect in various ways that were impossible under former conditions.

It is not true in point of fact that the operator of a modern labor-saving machine is restricted to the mere feeding of the machine with raw material; he is encouraged and expected to do very much more than this in order to obtain the best results. As an illustration, I may mention a case in point where two men work side by side, tending duplicate machines. One man earns nearly twice the wages of the other, for the simple reason that he can produce in ten hours nearly twice the quantity of finished material, made to standard measurements, the permissible limits of variation being probably but a few thousandths of an inch. The difference in efficiency is in the men, not in the machines.

It is not merely the ability to turn out a maximum amount of work from a modern machine that constitutes a skilled operative. No matter how nearly automatic the machine may be, it is still subject to human guidance, and no matter how nearly perfect its construction, its work is still subject to final correction and control by the hand of the operator. I am satisfied that in all trades where automatic machinery has been extensively introduced for the purpose, it may be, of supplanting hand labor, the ultimate result has proved beneficial to the workers in raising the general average of intelligence, and, furthermore, that it has largely increased the opportunities for labor.

This statement may appear at first sight somewhat paradoxical, but a little examination will, I think, convince you that it follows as a logical sequence. The cheapening of manufactured articles through the aid of machinery enlarges the demand and increases the production to such an extent that those things which were heretofore regarded as luxuries of the rich, soon become ordinary conveniences in the economies of life. This increased production necessitates the employment of a larger number of operatives than were formerly required to make the same articles by hand.

Several years ago a labor-saving machine (an electric travelling crane) was introduced into a certain department of a large manufacturing establishment, and immediately displaced no less than sixty helpers. Since then many other machines of like character have been installed, yet the number of workers in this establishment is more than 50 per cent. greater to-day than before, the total number of wage-earners in these works having risen from a little under 5,000 at the time alluded to, to over 8,000 men at the present time, and the works have grown to be the largest of their kind in the world.

The introduction of labor-saving machinery has proved beneficial to the workers in many other directions. It has shortened the hours of labor; it has improved the sanitary conditions in workshops; it has increased wages; it has increased the purchasing value of wages, and has elevated the social plane of the worker of the present day above that of his predecessors.

Finally, I may say that I believe the opportunities for advancement of the wage-earner in this country are to-day far greater than at any previous time, and that this fortunate condition of affairs is due largely to the educational influence of machinery upon the wage-earner, and to his emancipation from grinding toil by the aid of modern labor-saving machines.

The majority of men holding responsible positions in large industrial establishments to-day have risen from the ranks of the operatives. As a striking illustration I may allude to a remarkable instance, that of a comparatively young man who now stands at the head of the most stupendous industrial corporation the world has ever known, who, twenty years ago, began his work at the bottom of the ladder, and has risen to a position which is entirely unique, being now the central figure in the iron and steel industry of the country, and the president of a corporation with a capital exceeding $1,000,000,000! This is, of course, an extraordinary instance, and is not to be taken as representing an average case, but other illustrations might be given, all tending to show that the substitution of modern labor-

saving machinery for hand-labor has proven to be one of the greatest of all benefits to the wage-earner. The opportunities for lucrative employment and rapid advancement to young men properly equipped, entering the industrial establishments to-day, are greater than at any previous time within my recollection.

ANNUAL REPORTS OF THE DIRECTORS OF THE SCHOOLS OF DRAWING, MACHINE DESIGN, AND NAVAL ARCHITECTURE FOR THE SESSIONS 1900–1901.

THE DRAWING SCHOOL.—It is very gratifying to see the constantly increasing evidences of the usefulness of this school. In these days of large aggregations of capital, consolidation of works, division of labor, interchangeability of parts in manufacture, and the abolition of the apprentice system, a young man of average ability has but little opportunity to learn a trade in any general sense, or to add to his knowledge or secure his own advancement, except by such instruction and information as he can obtain in the evenings, outside and independent of his place of employment. Foremen and superintendents are too busy to assist or instruct their boys, and the work the latter can do, or the position they can fill, is becoming more and more dependent on their own energy and push and on their taking advantage of the opportunities offered by night schools, and less on the experience they can gain in their daily work. They may become very expert in the latter, but the very skill thus acquired makes them so valuable in that capacity that it chains them to that one thing.

A knowledge of the geometry, technicalities and conventionalities of drawing is so fundamentally essential to all industries that it should be the very first thing for the young man to obtain, and it is pleasing to see the increasing appreciation on their part of this fact. This knowledge once attained leads to a desire for mathematics, design, and special construction, and thus the technical education is built up.

The school has been large and well attended, and is maintaining and increasing its reputation, the credit for which is largely due to the instructors, Messrs. Clement Remington, Oscar Mowry, Albert F. Griffith, John Rae, and W. W. Twining.

WM. H. THORNE,
Director.

THE FOLLOWING STUDENTS ARE ENTITLED TO HONORABLE MENTION:

In the Senior Mechanical Class.

Frederick Schwartz,
Clarence Fithian,
Joseph Roberts,
Gustavus K. Focke,
Theodore R. Johnson,
A. K. Graham,
Frank Stoertz,
William J. Borton,
E. Winfield Finkbiner,
Henry Noske,
Henry Hobdell,
Luther Krout.

In the Intermediate Mechanical Classes.

Herman J. Ruch,
James Anderson, Jr.,
Edwin D. Bates,
Frederick Hartmeyer,
Richard Pockert,
Charles F. Miller,
William J. McFarland,
J. J. McGill,
E. L. Buckwalter,
Bernard G. Smith,
Julian Harwood,
Fred. W. Wiegand.

In the Junior Mechanical Classes.

Seward G. Dobbins,
Harry Hartranft,
John Marshall,
E. H. Berry,
William T. Sellner.

In the Architectural Class.

Duffield Ashmead, Jr.,
John L. McGarvey,
Samuel Miller.

In the Free-Hand Class.

Alfred G. Rose,
Roy E. Blithe,
Benjamin Feldman.

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND, ENTITLING THEM TO TICKETS FOR THE NEXT TERM:

Walter C. Chadwick,
L. Hastings Alexander,
J. W. Shaffer,
Harry H. Appleton,
Frank B. McDowell,
Roger W. Peterson.

THE FOLLOWING STUDENTS, HAVING ATTENDED A FULL COURSE OF FOUR TERMS, ARE AWARDED CERTIFICATES:

Frank E. Mahon,
John Limprun,
Clarence Fithian,
Gustavus C. Focke,
Frank Stoertz,
Herman Gutsche,
A. K. Graham,
Harry Hobdell,
E. Winfield Finkbiner,
Frederick Schwartz,
Edward J. Rowland,
Henry Noske,
Charles Weinerth,
Arthur G. Reinhilt,
J. B. Stevenson, Jr.,
Luther Krout,
William J. Borton.

The Germantown Junction Branch School, under the direction of Mr. Haakon Nortom, exhibits very satisfactory progress, and a large increase in the number of pupils. The following students are awarded certificates:

Edwin Kean Fagan,
Louis Ehlinger,
Spencer Ogborn,
Malcolm L. Baker,
Walter Andrews,
Frederick A. Steck.

THE SCHOOL OF MACHINE DESIGN.—The extension of the scope of the School of Elementary Mathematics to embrace subjects in a course in machine design has proved a very satisfactory step. The students who now

undertake the mathematical work offered, do so with a definite aim in view, instead of being left to their own resources after this is completed and, in consequence, evince a lively interest even in this preliminary work.

The subjects comprising the course in machine design proper are offered not merely as a feeder to the course in mathematics, but for their own intrinsic value to those who are interested in the design and construction of machinery, and no effort has been spared to make them of practical value and to present them in a logical and systematic manner. Indeed, the subjects, analytical mechanics and strength of materials, have been treated with unusual thoroughness for a course in which no higher mathematics is used, and many theorems, usually taken for granted in elementary works on these subjects, have been satisfactorily proved by the aid of special methods. It is unfortunate, in connection with this course, that the Institute does not possess the necessary laboratory equipment for carrying on tests of the strength of materials and of the efficiency of transmission devices; laboratory training of this kind being of undoubted value to the designer.

Next year the course is to be carried on substantially as already outlined and the only material change in view may be the cutting out of some of the work in mechanics and the addition to that in the strength of materials.

That the school bids fair to well serve its purpose, there seems very little doubt, if the interest shown by the students and their progress are an indication.

LUCIEN E. PICOLET, *Director.*

THE FOLLOWING PUPILS ARE AWARDED CERTIFICATES:

Charles Stone, William Williams,
Herbert E. Ives.

THE SCHOOL OF NAVAL ARCHITECTURE.—The School of Naval Architecture had, during the first half-term, thirty-one students, and during the second half-term twenty-five students. Six of these have attended the full term of two years, and will be graduated at the end of this term. The attendance at the lectures each week has always been up to the maximum.

The Senior Class has studied and examined all kinds of general arrangements and the details of fittings for same, and completed the necessary calculations that are required for the proper and efficient design of any vessel. They have made themselves proficient in the use of the integrator, estimating costs, calculating weights of material and centres of gravity, strength of structure of the hull under different conditions, as well as the powering of ships. Their home-work has shown wonderful energy, considering that the drawings, etc., are made without the help of the usual adjuncts of a drawing office. In fact, the graduating class has exhibited more than ordinary intelligence, and its members are neat and careful draughtsmen, zealous and painstaking.

The Junior students have progressed rapidly in both theoretical and practical naval architecture, and have also shown marked zeal in their work both in class and home work, numerous drawings and tracings having been made from blue prints which are beyond the average in neatness and accuracy.

A. J. MACLEAN,
Director.

THE FOLLOWING STUDENTS ARE AWARDED CERTIFICATES:

William H. Balls, Fred'k Austin Coolidge,
Gabriel Hofgaard, James A. Kelley,
Henry J. Hack, Joseph Rilatt.

BOOK NOTICES.

Report of the Geological Survey of North Dakota. (First biennial report.) By E. J. Babcock, State Geologist, Grand Forks, N. D. State Print. 1901. 8vo. Pp. 101, with numerous illustrations.

This is the first official contribution from the lately established Geological Survey of North Dakota, and the author wishes it to be regarded as a preliminary bulletin. It deals with the topography and geology, the clays of economic value, the coal deposits, and the water supplies of the State. W.

Experiments Arranged for Students in General Chemistry. By Edgar F. Smith (Professor of Chemistry, University of Pennsylvania), and Harry F. Keller (Professor of Chemistry, Central High School, Philadelphia). Fourth Edition. Enlarged with forty-one illustrations. Philadelphia: P. Blakiston's Son & Co. 1900. 12mo. Pp. 88. (Price, 60 cents.)

The plan of this work consists in the formulation of a progressive series of experiments in general inorganic chemistry, with problems appended, under each head, to accompany the regular course of class instruction.

The present edition (the fourth) has been improved by the introduction of new experiments, the modification of others described in the former editions, and a general revision of the text. W.

Analyse Chimique et Purification des Eaux Potables. Par P. Guichard, Membre de la Société Chimique de Paris, etc.

L'Industrie des Matières Colorantes Azoiques. Par George F. Joubert, Dr-ès-Sciences, etc. Paris: Gauthier-Villars, Masson et Cie. (Price, 2.50 francs in paper, 3.00 francs, pasteboard covers.)

These contributions to the valuable technical series issued by the publishers under the general title, "Encyclopédie Scientifique des Aide-Mémoire." Each is edited by an acknowledged expert, and concisely cover the subjects which are treated. W.

Traction and Transmission. A monthly supplement to *Engineering.* London, Eng. Vol. I. No. 1. April, 1901. (Price, 2 shillings net.)

The publishers of *Engineering* have issued the first impression of a monthly supplement to their widely-known journal, to be devoted to subjects relating to traction and power transmission. The new publication is issued in quarto form, and comprises fifty-six pages with numerous illustrations admirably printed on heavy paper in large type. The subjects treated are all useful contributions of a high order of merit. W.

Traité de la Fabrication des Liqueurs et de la Distillation des Alcools. Par P. Duplais ainé. Septième édition, entièrement refondue par Marcel Arpin, Chemiste industriel, et Ernest Portier, Répétiteur de Technologie agricole à l'Institut agronomique. Deux Volumes in-8 vendus séparément. 1900. Tome I: Les alcools. Volume de viii-613 pages avec 68 figures, 8 fr. Tome II: Les liqueurs. Volume de 606 pages avec 69 figures, 10 fr. Paris: Librairie Gauthier-Villars.

The present edition of this work has been completely revised by the editors and includes the latest advances in the technology of the manufacture of alcohol and liqueurs. Volume I exhibits the present state of our knowledge of alcoholic fermentation, with an exposition of the chemical and microbiological facts lying at the foundation of the art and the description of the various methods of distillation.

Volume II is devoted to the art of manufacturing these special products of the distiller which are known collectively as "liqueurs." W.

General Map of the Anthracite Coal Fields of Pennsylvania. Compiled under the direction of the Chief of the Division of Mining and Mineral Resources, U. S. Geological Survey. By Wm. W. Ruley, Chief of Bureau of Anthracite Coal Statistics, Philadelphia. Washington: Government Print, 1901.

This publication embraces a sketch map showing the local distribution of the three important anthracite coal fields of Pennsylvania—the Schuylkill, Lehigh and Wyoming fields; a table giving the figures of production of each field by years from 1820 to 1900, inclusive, and a graphical chart indicating the production by fields and the total output for the same period. W.

Electric Lighting. A practical exposition of the art for the use of engineers, students, and others interested in the installation or operation of electrical plants. Vol. II. Distributing System and Lamps. By Francis B. Crocker, E.M., Ph.D., Professor of Electrical Engineering in Columbia University, New York, etc. (Large 8vo, pp. vi–505.) New York: D. Van Nostrand Company: London. E. & F. N. Spon. 1901. (Price, $3.00.)

In his preface to this volume, the author, who is a well-known electrical engineer and teacher, explains that the work relates to the conductors for transmitting and distributing the current to the lamps and to the various auxiliary devices—switches, cut-outs, meters, etc.—employed with the same. The first half of the book, lately noticed, is devoted to the generating plants.

The first half of the present book is devoted to the properties of conductors and various systems of distribution, including direct current, as well as single and polyphase currents. Following this are chapters on overhead and underground conductors, arc lamps, interior wiring, incandescent and other forms of lamps, and electric meters.

There are two Appendices. The first gives in full the "National Electrical Code," containing the requirements according to which all electric lighting and other installations should be made, and the second gives the report in full of the Committee on Standardization of the American Institute of Electrical Engineers.

The book is printed in good style and is provided with an excellent index. W.

Handbuch der chemischen Technologie in Verbindung mit mehreren Gelehrten und Technikern bearbeitet und herausgegeben von Dr. A. P. Bolley und Dr. K. Birnbaum. Nach dem Tode der Herausgeber fortgesetzt von Dr. E. Engler, Geh. Hofrath und Professor der Chemie an der technischen Hochschule in Karlsruhe. Ersten Bandes dritte Gruppe. Die chemische Technologie der Brennstoffe. Von Dr. Ferdinand Fischer, Professor an der Universität in Göttingen. Braunschweig: Verlag von Friederich Vieweg u. Sohn. 1901. (Price, 15 marks.)

The volume above entitled forms one of the extensive series of "Bolley's Technologie," which for several years has issued from the press of Vieweg & Son, and which is widely known among chemists everywhere as an encyclopædic work on chemical technology of the highest order of excellence, compiled with the exhaustive thoroughness which usually characterizes German works of its class.

The volume is devoted to artificial fuel (briquettes), coke ovens, water gas, producer gas and mixed gases, and gas furnaces. The volume has 370 illustrations. W.

Technical Gas Analysis. By Frank H. Bates. (The Industrial Gas Series.) Vol. I. Philadelphia: Philadelphia Book Company. 1901. (Price, $1.00.)

This is the first volume republished in book form, of a series of articles on industrial gases, which appeared originally in the *Journal of Electricity*. The volume is intended by the author to serve as a guide in the selection of the best method and apparatus for use in making analyses of gases of varying composition—such as blast furnace gases, producer gases, flue gases, illuminating and other gases used for power purposes. The seven chapters of the book are devoted respectively to the collection of samples, methods of gas analysis, the Orsat apparatus, the Elliott apparatus, the Hempel apparatus, measurement of gases, and the properties of gases and preparation of reagents employed. W.

Tunneling. A practical treatise. By Charles Prelini, C. E., with additions by Charles S. Hill, C. E., Associate Editor *Engineering News.* 150 diagrams and illustrations. 8vo, pp. vi + 311. New York: D. Van Nostrand & Co. 1901. (Price, $3.00.)

This work has been prepared, as the author states, to meet the need of a text-book in the English language that would be suitable for use by engineering students. The large works of Drinker and Simms, while admirable expositions of the art and valuable for reference, are obviously unsuited for the purpose contemplated by the author, and he has accordingly sought to embrace in a work of convenient size and moderate price, an explanation of the various operations that are required in tunneling, with illustrations, by suitable examples, of the actual application of these methods in practice. W.

Report on the Census of Cuba. 1899. Lt.-Col. J. P. Sanger, Inspector-General, Director Henry Gannett, Walter F. Willcox, Statistical Experts. Washington: Government Print. 1900. 786 pp. 8vo, with numerous illustrations.

Those of our citizens in need of reliable statistical data concerning the Island of Cuba, its geography, history, population, agricultural and mineral resources, will find this publication a valuable compendium of information. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, May 15, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 15, 1901.

Vice-President WASHINGTON JONES in the chair.

Present, 96 members and visitors.

Additions to membership since last month, 21.

In connection with the several amendments to the By-Laws of the Institute, proposed at the stated meeting of April 17th, affecting the question of the annual dues of the contributing members, the Actuary reported the following resolution passed by the Board :

"RESOLVED, that the Board of Managers deems it inexpedient at this time to suggest any changes in the dues of members of the Institute, especially any changes that might reduce the revenues, which at this time are inadequate to meet current expenses, and recommends that action upon the amendments be indefinitely postponed."

On motion the resolution was adopted and the recommendation therein contained was approved.

The Secretary presented communications from His Honor the Mayor of Boston, respecting the proposed foundation of a Franklin Institute in Boston, with the proceeds of the Benjamin Franklin Fund; also a communication from the Verein Deutscher Ingenieure in reference to the proposition for the preparation of a technical dictionary in English, French and German, to the preparation of which the Franklin Institute has agreed to contribute ; also a letter from Prof. Arthur Beardsley, acknowledging his election as an honorary member of the Franklin Institute.

Mr. Morris Earle presented a description, with illustrations, of the electrical equipment of the physiological laboratory of the Jefferson Medical College, Philadelphia.

Discussed by Professor Rondinella and the author.

The subject was, on motion, referred to the Committee on Science and the Arts.

Mr. John S. Forbes described his apparatus for sterilizing water and exhibited the same in operation.

Mr. E. M. Walsh, of Janvier, N. J., exhibited and described his method of manufacturing "aventurine" glass—in large masses—suited for mantle-pieces, table-tops, etc.; an entirely new industry. The subject was referred to the Committee on Science and the Arts.

Mr. Fred. E. Ives exhibited and described the Chapman-Jones photographic plate tester, and likewise a novel form of lantern polariscope of his devising.

On motion, both subjects were referred to the Committee on Science and the Arts.

The Secretary made some reference to the death of the late Actuary of the Institute, David Shepard Holman, and on motion, the chairman was authorized to name a special committee to prepare a memorial of the deceased.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, May 1, 1901.*]

MR. LOUIS E. LEVY in the chair.

The following reports were presented for final action, and were approved :

(No. 2016.) *The Diesel Motor.*—Rudolph Diesel, Munich, Bavaria.

ABSTRACT.—The report contains a brief historical sketch of the development of the internal combustion engine, of which type the Diesel Motor is the latest and most advanced representative ; then proceeds to describe the special features of Herr Diesel's invention in respect of construction and operation ; then gives the results of various tests of the engine, some of which were participated in by members of the investigating committee. The report is reserved for publication in full.

The award of the Elliott Cresson Medal is made to the inventor. [*Sub-Committee.*—Henry Harrison Supplee, Chairman ; Arthur Falkenau, Coleman Sellers, Wilfred Lewis, Arthur M. Greene, Jr.]

(No. 2155.) *Chester Steel Tie for Railway Tracks.*—Philadelphia, Pa.

ABSTRACT :—This device consists of an inverted tie-bar of suitable weight and section, and for standard gauge tracks, 6 feet long. Near each end, the upper edge of this bar is slotted or notched out to receive the base of the rail, the outer edge of the notch being hook-shaped so as to fit over the flange of the rail. These two notches determine the gauge of the track. Immediately under each notch is placed a bearing-plate or chair consisting of a steel plate ¼ inch to ⅜ inch thick, 12 inches wide and 20 inches long, bent down at the ends forming inclined legs, about 5 inches long. These bearing-plates are slotted out so that the tie or gauge-bar can slip through them freely, and two cheek pieces or clips are stamped up from the under side, for the purpose of engaging with the inner base flange of the rail. No other fastenings of any kind are used.

In laying the tracks, it is only necessary to distribute the ties along the roadbed with the bearing-plates or chairs clipped towards the center of the track far enough to permit the rails to be placed in the notches of the gauge bars. When the rails are in position the bearing-plates are pushed out until the clips engage the inner flanges of the rail and the track is ready for tamping. The ballast alone is depended upon for holding the bars in position, the shape of the bearing-plates, it is claimed, being such as to insure this result.

The report admits the device to be simple in construction and ingenious in design, but states the following objections to its practicability, viz.:

The difficulty of opening and closing the gauge around curves without a special set of ties for each curve ; the difficulty of securing the track at switches and crossings ; of maintaining an accurate gauge owing to variations in the flanges of the rails and the wear in the notches ; the necessity of supplying new ties for every change of rail section ; the difficulty in taking out and replacing rails ; and lastly the impossibility of keeping the clamping devices tight under heavy and fast traffic. [*Sub-Committee.*—Thomas P. Conard, Chairman ; Henry F. Colvin, Charles Day, E. H. Johnson].

National Cash Register.—National Cash Register Company, Dayton, O.

ABSTRACT.—This apparatus in its present form is the subject of a large number of patents, many of them covering minor details of construction, and the present machine is the product of many minds.

The first machine was not a register at all, consisting simply of a set of pivoted levers with the numbered finger-piece at one end and the indicator at the other; no record being made.

The next step was to add a simple counter for each key and the amount was found by multiplying the number on the key by the number of times the counter showed it to have been depressed.

This was found to be troublesome, and counters were applied to each key, showing the amount credited thereon. This necessitated the taking off of these amounts on a slip and afterwards adding them to prove the cash in the drawer, and was done away with by attaching a "total adder" device, showing the whole amount at a glance.

These machines are operated by keys and the register is actuated by a spring motor.

The arrangement in construction has been improved from time to time, to prevent dishonest use, as practice has shown points of weakness until the outgrowth is the present machine.

For example: means were adopted to make a full depression of the keys necessary to full operation and to prevent improper registration in case the pressure ceased before full depression and was completed by a second pressure; also, means for locking the keys until the drawer was closed after each transaction.

The most approved type of the machine is actuated by a crank and uses depressable buttons (without levers) arranged in outwardly-curved columns, one to each indicating disk, duplicated to show any amount in dollars and cents and mechanically connected to the total adder.

A printing device is added which prints and throws out a check and also makes a record upon a slip. Means are provided for stopping the check, if desired, and printing upon the slip only, the difference in the intensity of the ink indicating no check. Should a clerk operate the apparatus and fail to give a customer a check, the slip tells on him.

These machines are furnished with a set of lettered buttons, each salesperson being designated by a certain letter and other buttons indicating the character of the transaction. For operation, the buttons indicating the amount of the purchase are first depressed, then the one showing the character of the transaction, then the letter showing the salesperson. This latter must be done. The machine is now set and the crank is turned one revolution, operating the indicators and registers and releasing the buttons, leaving it ready for the next transaction.

Other details devised to render more difficult the improper use of the machines for dishonest purposes are referred to in the report, but the principal items of the construction of the modern machine are noted in what has preceded.

The report concludes with the statement that "the registers fill the requirements of such an appliance thoroughly and are adapted to meet the necessities of all commercial business." The award of the John Scott legacy

Premium and Medal is recommended to be granted to F. J. Patterson, J. H. Patterson, Thos. Carney and Hugo Cook, the inventors of the more important features of the machine. [*Sub-Committee.*—Geo. S. Cullen, Chairman; Chas. Day, Lucien Picolet, W. C. L. Eglin.]

Waterhouse-Forbes Sterling Method and Apparatus.—Addison G. Waterhouse and John S. Forbes, of Philadelphia.

This report is reserved for publication in full. The award of the Elliott Cresson Medal is recommended. [*Sub-Committee.*—A. C. Abbott, M.D., Chairman; H. W. Spangler, Harry F. Keller, Philip Pistor.]

The following reports passed first reading:

(No. 2113.) *Liszt Organs.*—Mason & Hamlin Co., Boston, Mass.

(No. 2134.) *Improvements in Musical Instruments.*—Charles F. Albert, Philadelphia.

(No. 2166.) *Researches in Experimental Phonetics.*—E. W. Scripture, New Haven, Conn.

(No. 2167.) *Color Sense Tester.*—E. W. Scripture, New Haven, Conn.

(No. 2175.) *Balance for Testing White-Metal Alloys.*—Joseph Richards, Philadelphia.

(No. 2178.) *Micrometer Rolling-Mill Plate Gauge.*—Robert B. Haines, Philadelphia.

The following applications were dismissed for cause, without prejudice against renewal:

(No. 2153.) *Apparatus for Liquefying Aëriform Gases.*—M. Berger and O. P. Ostergren, New York.

(No. 2172.) *Wireless Telegraphy.*—G. Marconi, New York.

Awards in the cases of reports No. 2161 (subject: The Standard Voting Machine), and No. 2168 (subject: The Bardwell Votometer) were increased, on reconsideration, to a recommendation of the grant of the John Scott Legacy Medal and Premium in each case.

The special committee appointed to prepare and recommend a practicable system for indexing the committees' reports, through its Chairman, Mr. J. Logan Fitts, presented a report which, with its accompanying recommendations, was adopted, and the Secretary was directed to carry the same into effect upon receiving assurance that the Board of Managers would supply the needful funds for the purpose. W.

SECTIONS.

Abstracts of Proceedings.

PHYSICAL SECTION.—*Stated Meeting*, held Wednesday, April 24th, at 8 P.M. Dr. Geo. F. Stradling in the chair.

Prof. Wilbur M. Stine made the first communication on "E. H. Lenz, as one of the Founders of the Science of Electro-magnetism." Discussed by Messrs. Stradling, Landis, Hoadley and Pawling. Prof. Eric Doolittle, of the Flower Observatory, University of Pennsylvania, gave an interesting contribution on "Double-Star Astronomy." Discussed by Messrs. Hoadley, Landis, Stradling and Lloyd.

The chairman made a suitable allusion to the loss which physical science had sustained by the recent death of Prof. Henry A. Rowland.

JESSE PAWLING, JR.,
Secretary.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, April 25th. Dr. W. J. Williams in the chair. Present, 19 members and 2 visitors.

The paper of the evening was read by Dr. Robt. H. Bradbury, on "Some of the Researches of Professor Spring, of Liège." Discussed by Dr. Henry Leffmann, Dr. Harry F. Kebler, Dr. Wm. H. Wahl, Mr. Joseph Richards and others.

Dr. Keller called attention to the special value of such *resumés* as that which Dr. Bradbury had presented at this meeting, and, on his motion, the speaker of the evening was given a vote of thanks for his interesting and valuable communication.

W. H. WAHL,
Secretary pro tem.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, May 2, 1901. Dr. Chas. F. Himes in the chair. Present, 49 members and visitors.

Mr. F. V. Chambers inquired concerning the status of the resolution passed at the previous meeting requesting the official sanction of the Board of Man. agers of the Institute for the holding of the proposed photographic exhibition, Mr. Chambers was informed that the Board had as yet taken no action.

The chairman made some remarks explanatory of the condition of the plans for instituting a system of photographic record work by the section which had been in charge of the Executive Committee. He then made an informal address on the subject, suggesting some directions in which the Institute might do useful work of this kind.

Mr. F. E. Ives gave a description of a new lantern polariscope of his devising, which had the advantage of permitting the object to be laid flat upon the object stage, and also of permitting the instrument to be used for rendering lantern projections if desired without change except the interposition of a shutter. The speaker gave some interesting illustrations of the device.

Dr. Himes described and exhibited an exposure scale with a portable actinometer, the latter being an extremely compact and convenient device.

The same speaker likewise described and exhibited the Lothian stereoscope. This instrument is adjustable for interocular distance, which adds greatly to its efficiency. He likewise called attention to the superiority of the green ammonio-citrate of iron over the brown salt commonly used in the making of blue-prints, the first-named salt being much more rapid in its operation.

A resolution was adopted authorizing the President of the Section to appoint a special committee of five members to devise and report a plan of "Photographic Record Work."

WM. H. WAHL,
Secretary pro tem.